GAINFUL UTILIZATION OF SEGREGATED COMBUSTIBLE FRACTION (SCF) RECOVERED FROM BIOMINING OF LEGACY WASTE DUMPSITES IN INDIA

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Maps used in this document are not to scale.

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1. Introduction

- **Combustible materials such as plastics, leather and clothes are excavated as end products of the legacy waste dumpsite remediation process. These segregated combustible fractions (SCF) are typically contaminated with inert material and high moisture content.**
- **Combustible fractions constitute about 8–20 per cent of the legacy waste in an old dumpsite, which means India must deal with nearly 18–46 million tonnes of combustible materials in the total 230 million tonnes of legacy waste lying in dumpsites.**
- **One of the primary hurdles in managing SCF during dumpsite remediation lies in the substantial transportation costs associated with the process (cost in transporting the SCF to cement co-processing units or waste-to-energy plants).**

There has recently been a paradigm shift in waste management policy in India that has cleared the path for remediation of legacy waste dumpsites while repudiating the arguments and excuses against it. Swachh Bharat Mission (SBM) 2.0 has earmarked a mammoth financial outlay of Rs 1,41,600 crore, with focus on source segregation, material recovery facilities, phasing out single-use plastic, construction and demolition waste processing, and remediation of all legacy dumpsites in the country. As India strives to establish a more scientific and sustainable solid waste management system, guided by the principles of circular economy, it cannot allow the efforts to be weighed down by legacy waste accumulated in the existing operational and non-operational dumpsites in the cities..

According to SBM 2.0 operational guidelines given by the Ministry of Housing and Urban Affairs (MoHUA), cities with a population of under 1 million should have eliminated legacy waste sites by 31 March 2023, while cities with a population of 1 million or more must clean up their dumpsites by 31 March 2024. In any case, all the existing dumpsites in India should ideally be cleared by the end of the second phase of SBM. In unscientific landfills (commonly referred to as dumpsites), legacy waste is generally old municipal solid waste (MSW), which contains partially or totally decomposed organic waste, plastic waste, textiles, metals, glass, and other materials.

It is significant to highlight that legacy waste dumpsite remediation programmes in India are concerned not only with older unscientifically managed dumpsites but also with any dumpsite that is still relatively new and receiving fresh garbage every day. The goal is to clean up poorly managed and unscientifically planned dumpsites that are posing long-term risks to the environment and public health.

While the mandate under SBM 2.0 looks very promising with commitment for substantial financial devolutions by the Government of India to remediate the existing dumpsites, it also presents unique challenges. It has been recognized that a proper roadmap to divert the recovered materials—including combustibles like plastics, paper, textiles, leather, wood, etc.—obtained during the process of biomining would be extremely critical to the success of the whole endeavour of dumpsite remediation.

Combustible fractions typically constitute about 8–20 per cent of the legacy waste in an old dumpsite. That means India has to deal with nearly 18 to 46 million tonnes of combustible materials in about 3,159 dumpsites in the country. Combustible materials are excavated as end-products of legacy waste dumpsite remediation process. These segregated combustible fractions (SCF) are typically contaminated with inert material and high moisture content (more than 30 per cent), which makes them not so desirable for cement factories or any other treatment process.

As a result, many urban local bodies (ULBs) are struggling to find economically viable options for disposal of recovered material, including the combustibles. Presently, the only available option is co-processing in cement industries. Co-processing refers to the use of waste materials having high calorific value as alternative fuels or raw material (AFR). Due to the high temperature in cement kilns, different types of wastes can be effectively disposed without harmful emissions.

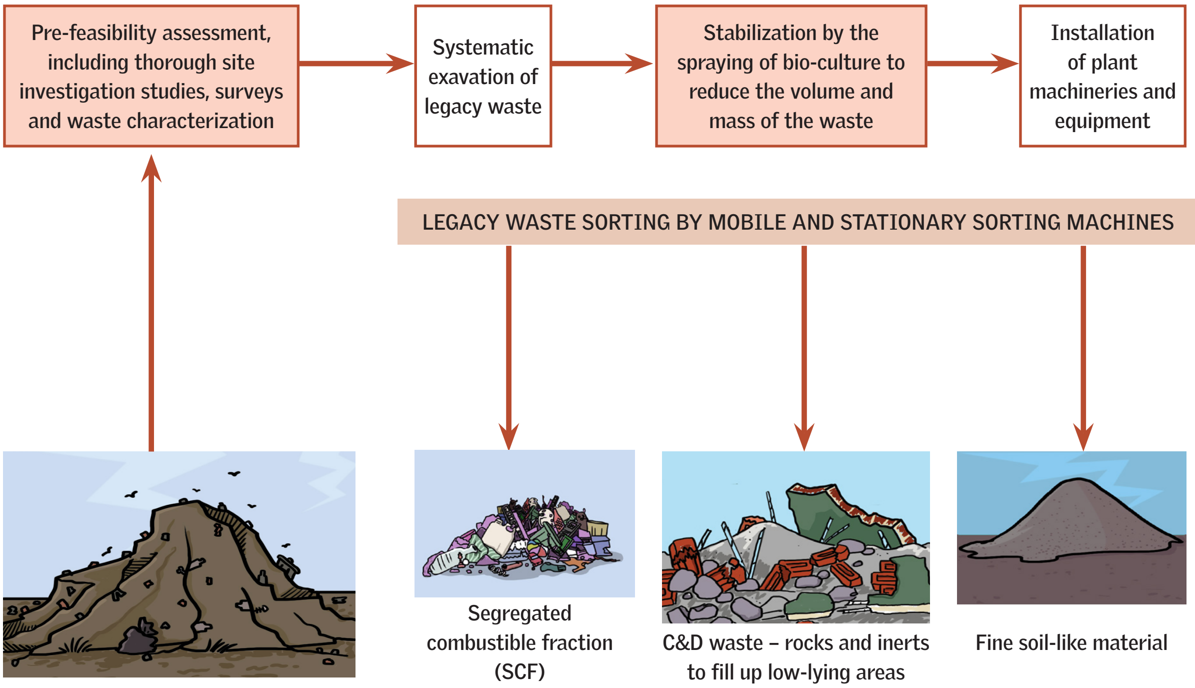
Fate of combustibles in landfills and their environmental hazards

Combustible materials, when disposed of in landfills, pose significant hazards, particularly when they catch fire, especially during the hot summer months and under specific environmental conditions. This is a critical concern, as the combustion of such materials, including plastics, can lead to air pollution and the release of harmful gaseous pollutants.

Plastics, being non-biodegradable in nature, contribute to various long-term environmental issues when deposited in landfills. Upon reaching a landfill site or an open dumpsite, plastics typically exist in the form of macroplastics, which are larger in size.

Over time, these macroplastics undergo processes such as weathering and fragmentation, due to which significant changes occur in their chemical structure

Figure 1: Segregated combustible fraction (SCF), C&D waste and fine soil-like material derived from biomining of legacy waste dumpsites



Source: CSE

Table 1: Different components in SCF typically recovered from a legacy waste dumpsite in India

LDPE	Carry bags
PET (polyethylene terephthalate)	Plastic bottles – water, soft drinks
HDPE	Shampoo bottles, detergent bottles, hard plastic bottles, etc.
Multi-layered plastics	Chips and toffee wrappers, tetra packs
PU (poly urethane)	Foams
PP (polypropylene)	Caps of PET bottles, ropes, twine, tape, carpets, etc
PS (polystyrene)	Thermocol cutlery
PVC (polyvinyl chloride)	Sewage pipes and other pipe applications, insulation on electrical wires
Textiles	Soiled clothes
Footwear	End-of-use shoes and slippers
Leather and rubber	Leather and rubber items
Ply and wood	Ply and wood items
Others	Sanitary pads and other items (look like plastics) which are difficult to recognize

Source: CSE

under specific environmental conditions, resulting in the loss of some of their properties. Polymeric characteristics play a significant role in the degradation. These characteristics include molecular weight, crystallinity, functional groups, mobility, substituents present in the structure, and the additives added to the polymers. Polymers can be degraded via chemical degradation, photodegradation, and biological degradation, which may lead to the formation of secondary microplastic pollution. Consequently, both macroplastics and microplastics coexist in landfill sites, amplifying the environmental impact.

The presence of both macroplastics and microplastics in landfills indicates the complexity of plastic waste management and emphasizes the need for effective strategies to minimize their entry into landfill sites. This includes implementing better waste disposal practices, promoting biomining, and exploring more environmentally-friendly alternative materials. It is crucial to address these challenges to mitigate the environmental consequences associated with plastic waste in landfills.

Once in landfills, waste initially undergoes aerobic biodegradation but swiftly transitions to anaerobic conditions, influenced by acid formation and methane fermentation from organic solid wastes. In the absence of light and oxygen, microplastics persistently fragment into nanoplastics due to fluctuating temperatures (reaching up to 60–90 °C), varying pH (4.5–9), deep-seated fires, physical stress, compaction and limited microbial activity. These factors accelerate the breakdown of plastics. While most polymers in landfills remain unchanged, some may degrade through biotic or abiotic processes into fragments that either persist or biodegrade into gaseous products and water. In aerobic environments, the gaseous products consist mainly of carbon dioxide.

Potential pathways for the transfer of plastic debris from landfills to the environment

Potential routes for plastic losses from landfills involve environmental mechanisms—like wind, flooding, leaching, and runoff—as well as the impact of living organisms, such as their littering by animals.[1] Engineered landfills, which are sanitary and well-managed, are equipped with physical barriers to prevent these kinds of losses. Their locations are typically chosen for their environmental attributes, which significantly decrease the likelihood of plastics escaping into the environment. In contrast, open dumps lack effective barriers to prevent plastic losses. They lack fencing to hinder the movement of macroplastics through winds, runoff, or floods and lack liners to impede the movement of microplastics through leachate.

In the presence of elevated pore pressure resulting from the accumulation and extrusion of waste, the movement of leachate and landfill gas may induce diverse ageing effects on plastic waste, involving processes such as rinsing, immersion, collision and corrosion.[2] As part of the landfill stabilization process, the gradual settling of waste can lead to the mechanical breakdown of plastic waste through friction and sheer force.

Despite studies recognizing the potential risk of plastic waste for microplastic generation in landfills, information on the ageing and fragmentation of plastics under such unique light-avoided and complex environmental conditions in landfills remains limited.

Impacts of plastics released from landfills

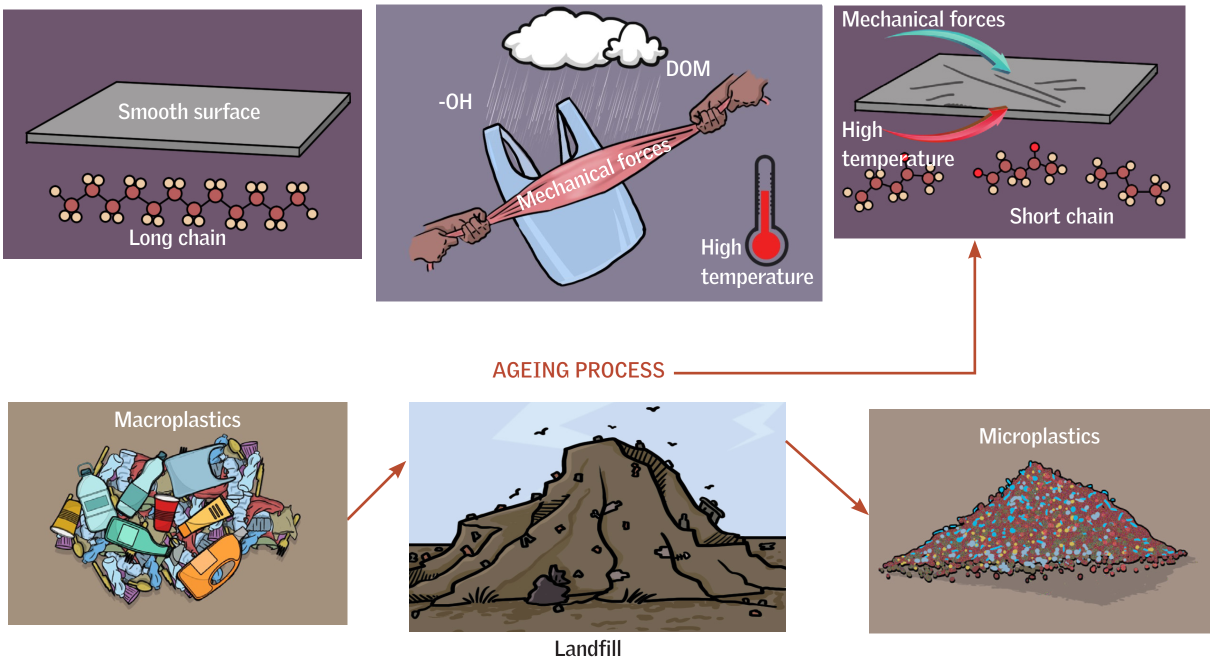
Leachate contamination: Rainwater or other liquids percolating through the waste in landfills can create leachate, a liquid that can contain various pollutants, including microplastics and harmful chemicals. If not properly managed, leachate can migrate into surrounding soil and water, leading to pollution. Microplastic (typically polyethylene, polystyrene and polypropylene) concentration in raw and treated landfill leachate varies between 0–382 and 0–2.7 items per litre respectively, as reported by a recent study conducted by North Carolina Agricultural and Technical State University, USA.[3] Another study conducted by the NIT Andhra Pradesh reported the presence of microplastics concentrations in landfill leachate in Hyderabad ranging between 9 and 21 items per litre. The most common microplastic shape was fibre (83 per cent), followed by fragment (11 per cent), film (3 per cent), and foam (2 per cent). The colour of microplastics found in leachate was yellow (35 per cent), transparent (16 per cent), purple (15 per cent), blue (11 per cent), pink (8 per cent), white (6 per cent), black (3 per cent), green (2 per cent), and orange (1 per cent). From the chemical analysis the predominant polymers detected were LDPE, PP, PET, CA, and Nitrile.[4]

Wind dispersal: Lightweight plastic particles, such as microplastics or small plastic fragments, can be carried by the wind. Inadequately covered or managed landfills may release plastic particles into the air, contributing to pollution in nearby regions.

Surface runoff: Rainwater can wash over the surface of landfills, picking up plastic debris and contaminants. This runoff may flow into nearby waterbodies, introducing plastics and associated pollutants into aquatic ecosystems.

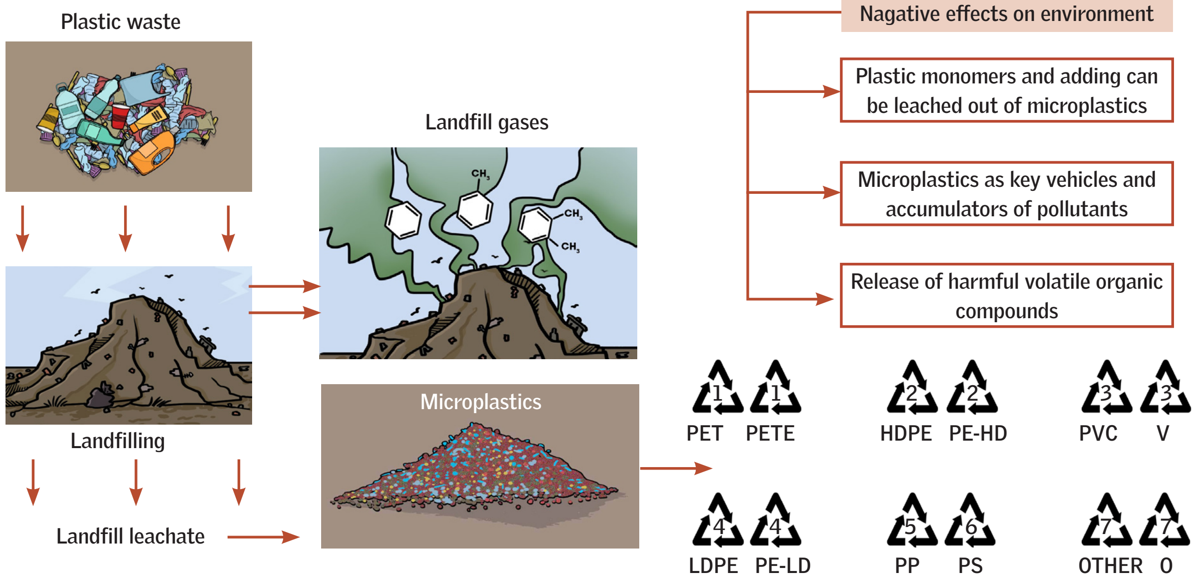
Flooding events: During heavy rainfall or flooding, landfills may become inundated, causing plastic waste to be carried away by floodwaters. This can result in the spread of plastics and contaminants to downstream areas.

Figure 2: Macroplastics and microplastics generated from legacy waste dumpsites



Source: Q. Huang et al 2023. "Exploring into a light-avoided environment: Mechanical-thermal coupled conditions responsible for the aging behavior of plastic waste in landfills," *Water Research*.

Figure 3: Impacts of legacy combustibles (primarily plastics)



Source: I. Wojnowska-Baryła, K. Bernat and M. Zaborowska 2022. "Plastic waste degradation in landfill conditions: the problem with microplastics, and their direct and indirect environmental effects," *International Journal of Environmental Research and Public Health* 19(20).

Biological transport: Animals, attracted to landfills for food or shelter, may carry plastic waste away from the landfill site. This can contribute to the dispersal of plastics into surrounding regions.

Lack of engineering controls: In poorly managed or unengineered landfills, where physical barriers and containment systems are insufficient, there is a higher risk of plastic pollution. Open dumping without proper waste containment measures can lead to widespread environmental contamination.

Challenges and issues with disposal of SCF

Currently, combustible materials—including macroplastics, textiles, wood and leather—buried in landfills or dumpsites are being managed through biomining operations in most of the cities in India in accordance with the SBM 2.0 guidelines. However, one of the primary hurdles in managing SCF during dumpsite remediation lies in the substantial transportation costs associated with the process (cost in transporting the SCF to the cement co-processing units or waste-to-energy plants).

A relevant example is the Bombgarh dumpsite in Leh, where transporting SCF to co-processing plants poses a tough challenge due to the uneven terrain and the site's inaccessibility to cement plants. The distance of the closest co-processing plants, located in Himachal Pradesh (approximately 640 km away) and Srinagar (approximately 416 km away), further aggravate the logistical difficulties.

Another critical aspect is the quality of the SCF. Cement co-processing plants demand a specific quality and quantity of waste, yet consistently supplying them with high-quality waste remains a challenge. This difficulty arises from the fact that legacy waste often contains substantial amounts of fine soil-like material and moisture content, significantly diminishing its calorific value (CV). The presence of these contaminants compromises the efficiency of the cement co-processing units and other waste-to-energy conversion processes, posing an additional obstacle in effectively managing SCF disposal.

The disposal of SCF recovered from legacy waste dumpsites is an urgent requirement and needs to be prioritized. Mechanisms to help ULBs develop some SOPs to enhance the quality of the SCF are also required. Besides, creating a win-win situation for both the cement factories and ULBs could potentially contribute in making the whole endeavour of dumpsite remediation successful.

CHARACTERIZATION & COMPOSITIONAL ANALYSES OF SCF FROM EXISTING DUMPSITES

CHARACTERIZATION & COMPOSITIONAL ANALYSES OF SCF FROM EXISTING DUMPSITES

To investigate and understand the composition and characterization of SCF recovered through the biomining process from various dumpsites, a study was conducted which involved the systematic collection of samples from four distinct sites, using the grab sampling method. The aim was to obtain representative samples that could provide insight into the varied nature of the biomined materials.

Upon sample collection, the composition of SCF was analysed using a simple hand-picking process. The SCF was categorized into specific groups, including plastics (such as PP, HDPE, LDPE, PVC, multilayered, etc.), textiles, footwear, leather, and a category denoted as 'others'. The 'others' category was designated for materials like soiled sanitary pads or those challenging to identify. Inerts, within this context, referred to fine soil-like materials and fine aggregates.

Following categorization, the calorific value of the different components was estimated using a bomb calorimeter. This step aimed to quantify the energy potential inherent in each categorized material, providing valuable insights into potential applications and overall energy recovery from SCF.

In addition, the study estimated crucial parameters of SCF such as moisture, ash and sulphur content. This analysis contributed to a comprehensive understanding of the physical and chemical properties of SCF, essential for formulating effective waste management strategies and exploring sustainable utilization pathways for the recovered materials.

KUBERPUR DUMPSITE IN AGRA

Age of the dumpsite **~12 years**

Total dumpsite area **42 acres**

Accumulated waste quantity **~21 lakh tonnes**

Dumpsite remediation **Yes**

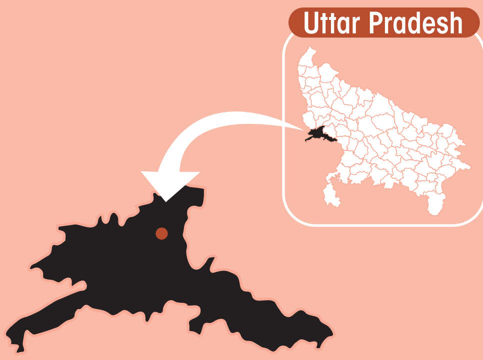
Legacy waste treated so far (October, 2023) **11.50 lakh tonnes**

Legacy waste to be remediated (October, 2023) **10 lakh tonnes**

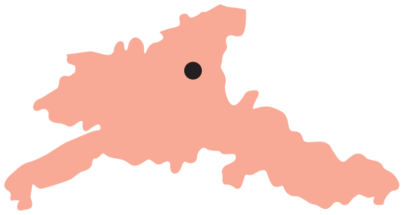
Waste utilization*

Legacy waste treatment and disposal cost **Rs 324 per tonne**

Percentage of segregated combustible fraction **12–15**



*Fine soil-like material for labelling of land and as a filler material in low-lying areas. C&D waste to C&D waste processing plant (20 TPD), RDF to be used in waste-to-energy plant. Presently stored at the Kuberpur site.



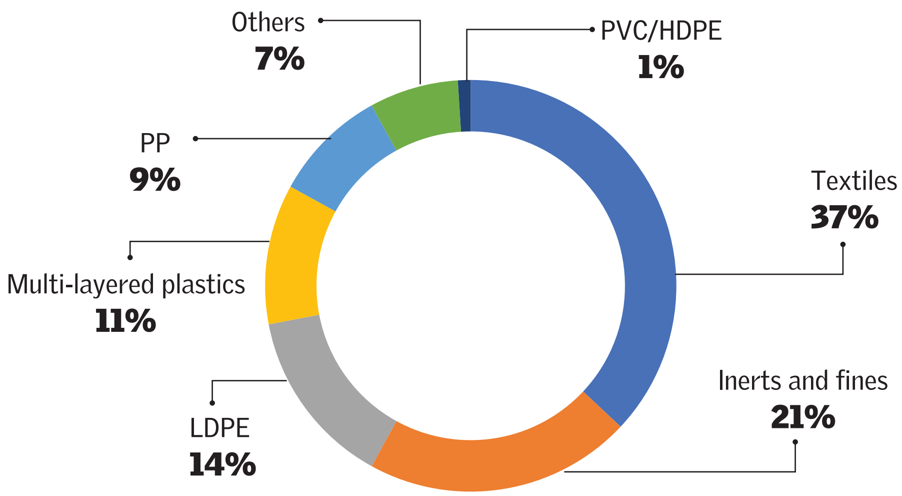
Agra is situated along the Yamuna River in Uttar Pradesh, approximately 210 kilometres south of the national capital, New Delhi. According to the 2011 Census, Agra had a population of 1,585,704.[5]

The city generates approximately 850 metric tonnes of municipal solid waste daily. Before 2019, Agra lacked proper waste recycling facilities or a well-designed functional sanitary landfill site in compliance with the Solid Waste Management Rules of 2016. Unsorted waste was indiscriminately disposed of at the Kuberpur dumpsite.

In October 2019, the Agra Municipal Corporation (AMC) started a biomining project to address the 9.4 lakh tonnes of accumulated waste at the Kuberpur site. This initiative was successfully completed in March 2022. After confirming its physical and chemical characteristics, the fine soil-like material extracted was utilized to fill low-lying areas and level another section of land on the existing site. Construction and demolition (C&D) waste from the project was integrated into the site for the construction of a temporary road, the establishment of a green park, and the installation of fencing. The remaining C&D waste is currently undergoing processing at a 5-tonne-per-day (TPD) C&D waste processing plant, built on a 3-acre (1.21 hectare) section of the reclaimed land.

The Agra Nigar Nigam is in the planning stages of establishing a waste-to-energy plant and revamping the sanitary landfill facility within the site premises.

Graph 1: Composition of SCF obtained from the Kuberpur dumpsite in Agra



SCF recovered from biomining of Kuberpur site temporarily stored in a storage shed

The recovered SCF is securely stored in a shed and will serve as fuel in the waste-to-energy plant. Ferrous materials were segregated using magnetic separators, and other valuable materials were sold to local recyclers.

Composition and characterization of SCF at the Kuberpur dumpsite

Analysis of the SCF sample procured from the dumpsite reveals a diverse composition, providing essential insights into the nature of the waste. The predominant presence of textile waste at 37.50 per cent suggests a significant accumulation of discarded materials such as soiled cloths, gunny bags, etc. in the waste stream in Agra City. This finding highlights the importance of targeted waste management strategies, particularly for textile waste, which poses unique challenges due to its complex composition and potential environmental impact.

Plastic components also feature prominently in the SCF sample, with LDPE packaging material at 14.50 per cent and multilayered packaging material at 10.90 per cent. These materials indicate potential for energy recovery through controlled incineration or in cement co-processing plants. The high calorific value of LDPE, as discussed in the present analysis, emphasizes its potential as a valuable resource for energy generation.

Polypropylene (PP) packaging, at 8.6 per cent, adds another layer to the plastic composition within the sample. PP is recognized for its heat resistance, suggesting its suitability for combustion processes aimed at energy retrieval. The low presence of HDPE at 0.70 per cent signals a comparatively minor contribution of these materials to the combustible fraction which is perhaps a good indicator about informal recycling in Agra city.

Table 2: Calorific value (CV) estimation of SCF obtained from Kuberpur dumpsite in Agra

Sr. no.	Sample type	Calorific value (Cal/g)	Representation %	CV contribution (Representative % * CV)	Calculated average CV of heterogenous mix (kCal/kg)
1	Textile	2,413.47	40.24	971	4,099
2	HDPE/PVC	10,148.5	0.75	76	
3	LDPE carry bags	6,965.21	15.56	1,084	
4	Polypropylene	8,357.61	9.23	771	
5	Multilayered plastic packaging	9,653.21	11.70	1,129	
6	Fine materials and inerts	300	22.53	68	

Waste sample from Agra dumpsite before sorting

Sample sorted and labelled into different categories

Inerts or fine soil like materials recovered from Agra sample

The presence of inerts and fine materials at 21 per cent highlights the existence of non-combustible components, highlighting the importance of waste sorting and segregation for effective waste management. Additionally, the category labelled as "Others" with miscellaneous items at 6.70 per cent indicates the presence of diverse materials that may require specific handling methods.

Analyses of SCF sampled from the Kuberpur dumpsite

The analysis of samples collected from various locations in Agra reveals significant variations in the calorific values and composition of different sample types. The sample mixed with refuse derived fuel (RDF) exhibits a calorific value of 4,099 Cal/g, equivalent to 17.16 MJ/kg, with a total sulphur content of 0.36 per cent, moisture content of 2.731 per cent, and ash content of 15.947 per cent.

In comparison, the textile sample has a higher calorific value of 2,413.47 Cal/g (10.097 MJ/kg). The LDPE sample stands out with an exceptionally high calorific value of 10,148.5 Cal/g (42.46 MJ/kg), emphasizing its potential as a high-energy fuel source. Similarly, the polythene bag, polypropylene and multilayered plastic samples also exhibit high calorific values of 6,965.21 Cal/g (29.142 MJ/kg), 8,357.61 Cal/g (34.968 MJ/kg) and 9,653.21 Cal/g (40.389 MJ/kg) respectively. On the contrary, inerts or fine materials have a negligible calorific value of 300 Cal/g.

These results highlight the diverse energy potentials of different waste materials and highlight the importance of considering both calorific values and composition when assessing their suitability for energy recovery or waste management purposes. Further analysis and comprehensive data collection for all sample types would enhance the accuracy and reliability of these findings.

LIMITATIONS OF THE STUDY

Limitations of the present analysis should be acknowledged, particularly with respect to the recorded percentages of each waste stream in the SCF sample. It is crucial to recognize that the observed percentages may be lower than what would be encountered in real-world scenarios, given the potential presence of inert contaminants and fine materials in the samples collected directly from the site. The inclusion of inerts, which do not contribute to combustion or recycling processes, can artificially inflate the percentages obtained in the analysis.

To obtain more accurate results reflective of the true combustible fraction, a thorough washing of the sampled materials would be necessary. This additional step aims to eliminate any inert contamination, providing a more precise representation of the actual composition of the combustible waste. It is anticipated that the results from such a meticulous washing process would likely yield lower percentages than those obtained in the initial analysis.

However, the present approach, despite its limitations, holds practical significance for on-ground applications by city officials or contractors. The method adopted in this analysis allows for a quick estimation of the composition percentage, offering a practical and feasible approach for initial assessments at waste disposal sites. The simplicity and ease of implementation make it a valuable tool for preliminary evaluations, facilitating swift decision-making processes and resource allocation. While recognizing its limitations, this practical approach enables a preliminary understanding of waste composition that can inform initial waste management strategies.

Another limitation could be the size of the sample. In the present study, the size of the sample is limited to 25–30 kg. However, efforts have been taken to collect grab samples from at least 5 spots at the dumpsites so that a representative sample could be prepared.

WHAT CAN GO WRONG WITH CV ESTIMATION?

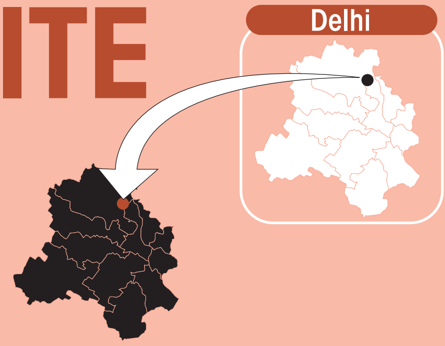
The heterogeneity of SCF implies that it consists of a diverse mixture of combustible materials with varying calorific value, including textile waste, different types of plastic waste (such as HDPE, LDPE, PET, etc.), and other miscellaneous items. Since SCF encompasses a wide range of components, each with its distinct energy content, accurately estimating the calorific value requires a representative sample.

When assessing the calorific value of SCF, it is common practice to take samples for analysis using a bomb calorimeter. However, due to the heterogeneity of SCF, the composition of these samples may not fully capture the variability present in the entire waste stream. If the sample used for calorific value estimation is not representative, it may not adequately reflect the true average composition and energy content of the overall SCF derived from a legacy waste dumpsite.

For example, if a calorific value analysis is conducted on a sample that unintentionally overemphasizes certain high-energy components, such as plastics or textile, the calculated calorific value might be higher than the actual average for the entire waste stream where a major fraction is inerts (up to 30 per cent by weight). Conversely, if the sample disproportionately includes low-energy materials, the calorific value could be underestimated. Typically, in most of the cases, the calorific value of SCF tested by many laboratories is overestimated due to lack of understanding regarding this factor.

Inaccuracies in the representation of the waste stream can lead to misleading results and impact decision-making in waste management, especially in contexts where the energy potential of SCF is a critical factor, such as in cement co-processing industry or waste-to-energy applications.
To mitigate this issue, it is crucial to adopt sampling protocols that ensure a fair representation of the various materials within SCF. This may involve taking samples from different locations, times and depths to account for the heterogeneity and variability of the waste stream. Also, it is critical to pulverize the sample to prepare a homogeneous mixture or to estimate the CV of all the components of SCF and average that. This can provide a more accurate representation of the overall SCF composition and calorific value.

OKHLA DUMPSITE IN DELHI



Age of the dumpsite **~27 years**

Total dumpsite area **40 acres**

Accumulated waste quantity **Around 45 million tonnes**

Dumpsite remediation **Ongoing**

Legacy waste treated so far (October, 2023) **18 lakh tonnes**

Legacy waste to be remediated (October, 2023) **30 lakh tonnes**

Area of recovered land **8–10 acres**

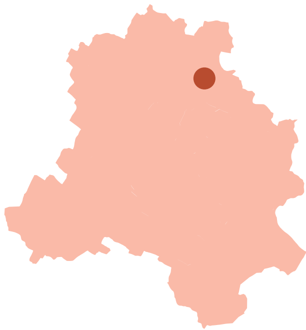
Waste utilization*

Total project cost **Rs 230 crores**

Legacy waste treatment and disposal cost **Rs 745 per tonne**

Percentage of segregated combustible fraction **15-20**

*C&D waste and fine soil-like material to NHAI accredited sites, RDF to the cement co-processing plants.



The landfill located in Okhla, Delhi, served as a waste dumping site for the South Delhi Municipal Corporation (SDMC) since it was commissioned in 1996. Spanning an area of 40 acres, the landfill became a crucial component of waste management in the region. Despite its designation as exhausted in 2010, a significant portion of the daily waste generated in SDMC, approximately 1,200 tonnes out of 3,500 tonnes, continued to be deposited at the Okhla Landfill.

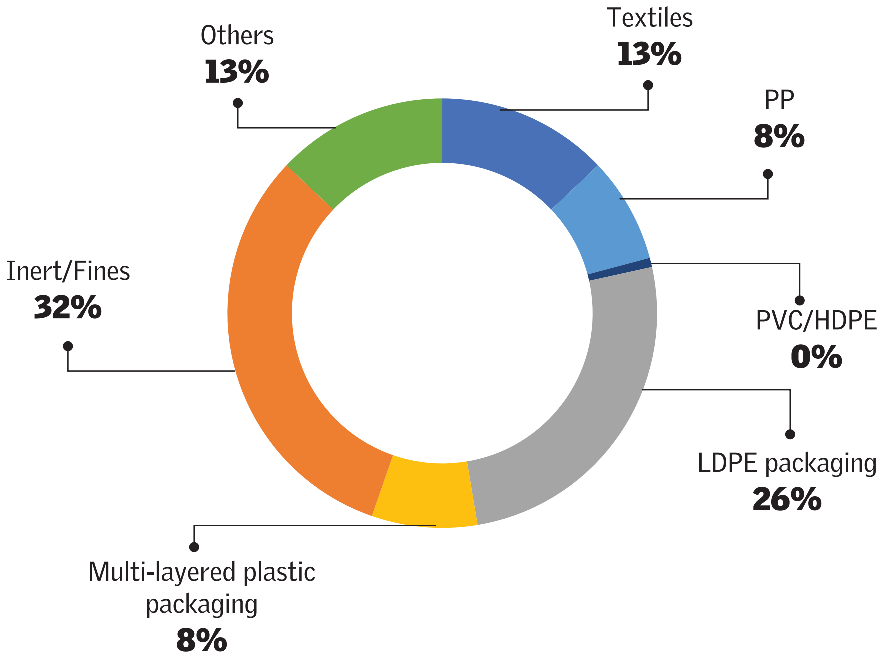
By 2018, the landfill had exceeded permissible limits, reaching a height of 55 meters, prompting environmental concerns. Recognizing the urgency of the situation, the site was officially decommissioned in 2018.

The civic agency responsible for waste management has now set forth an ambitious plan for the Okhla landfill. The primary objective is to complete the remediation process within one-and-a-half years, aiming to convert the landfill into a revitalized and reclaimed space. This transformation initiative aligns with broader sustainability goals, emphasizing the commitment to mitigating the environmental impact of landfills and repurposing urban spaces for the benefit of the community.

Composition and characterization of SCF at the Okhla dumpsite

The compositional analysis of SCF from the Okhla dumpsite provides crucial insights. The prevalence of 32 per cent inert content in the SCF indicates a

Graph 2: Composition of SCF obtained from the Okhla dumpsite



substantial presence of non-combustible and fine materials. Inerts contribute to ash formation during combustion, potentially reducing the calorific value of the waste stream. This poses challenges to combustion efficiency and raises concerns about the overall quality of the recovered materials.

Several factors may contribute to the elevated inert percentage observed. Inadequate sorting and segregation processes during biomining operations may result in the inclusion of non-combustible materials. Additionally, the nature of the waste stream, influenced by disposal practices and the types of materials discarded, can contribute to the observed inert content.

To address the challenges associated with high inert content, several strategies can be considered. Implementing advanced sorting technologies, such as air density classifiers or near-infrared sensors, can enhance the precision of material separation, reducing the inclusion of inert materials. Additionally, regular monitoring and audits of waste processing facilities can identify areas for improvement in segregation practices.

Table 3: CV estimation of SCF obtained from Okhla dumpsite in Delhi

Sr. no.	Sample type	Calorific value (Cal/g)	Representation %	CV contribution (Representative % * CV)	Calculated avg CV of heterogenous mix (kCal/kg)
1	LDPE	5,876.51	26.00	1,528	3,298
2	Polypropylene	4,743.95	8.00	380	
3	Multi-layered plastic	7,156.64	8.00	573	
4	Fines, inerts	120	32.00	38	
5	Textiles	5,000.00	13.00	650	
6	Others	1,000.00	13.00	130	

The characterization of SCF provides valuable insights into the energy potential and composition of specific waste materials. The presence of polypropylene, with a CV of 4,743.95 Cal/g, and multilayered packaging with CV more than 7,000 Cal/g showcase suitable for energy recovery through combustion. The relatively low moisture content of 3.25 per cent suggests the SCF is sufficiently dry for effective combustion. This is crucial for maximizing the calorific value and energy recovery during incineration or other thermal treatment methods. Additionally, the low sulphur content of 0.45 per cent is promising, indicating reduced emissions of sulphur compounds during combustion, aligning with environmental sustainability goals.

On the other hand, the ash content is recorded at 35.62 per cent, signifying a notable proportion of inorganic, non-combustible residue. While high ash content may impact energy yield, it is essential to assess this in the context of specific end uses and consider refining processes to optimize energy recovery. Overall, understanding these parameters enables informed decision-making regarding the potential applications and optimization strategies for the SCF from the Okhla dumpsite.

Further detailed analysis and complete characterization of all components are essential to gain a holistic understanding of the SCF and optimize its utilization in a sustainable and environmentally conscious manner.

Analyses of SCF sampled from the Okhla dumpsite after installation of Air Density Classifier (ADS)

The compositional analyses of SCF from the Okhla dumpsite in Delhi, before and after the installation of the Air Density Classifier (ADS), highlights significant improvements in the handling of inert materials.

Air density classifier (ADS) for segregation of SCFs from biomining of legacy waste

Prior to ADS installation, SCF composition included a substantial 32 per cent of inerts or fine materials. Following the installation of the ADS, that number has fallen to 21 per cent. This considerable decrease signifies the effectiveness of ADS in better segregating and removing inerts, dust and fine materials from SCF. Minimizing the presence of inert materials is essential for optimizing subsequent waste management processes, such as incineration or energy recovery, and can lead to more efficient utilization of SCF recovered during biomining.

The successful reduction in inert percentages indicates that the ADS plays a pivotal role in improving the overall quality of SCF. By enhancing the precision of material separation, the ADS contributes to a cleaner and more refined waste stream, aligning with sustainable waste management practices and promoting the efficient recovery of valuable resources.

Graph 3: Composition of SCF obtained from Okhla dumpsite in Delhi after installation of ADS

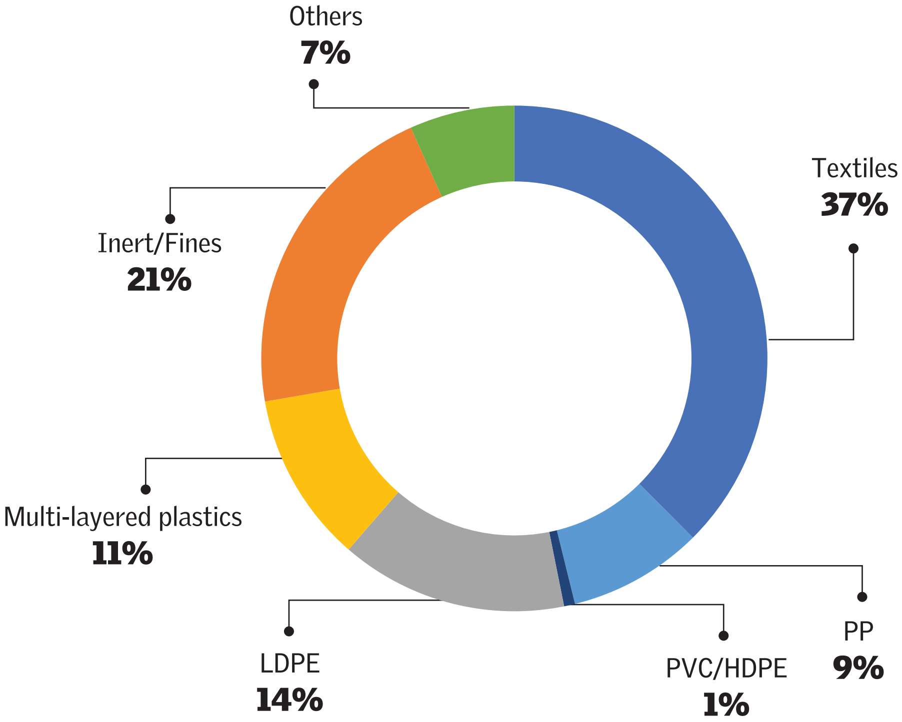
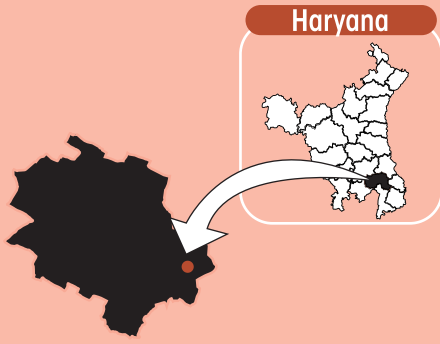


Table 4: Calorific value of SCF at Okhla dumpsite after installation of ADS

Sr. no.	Sample type	Calorific value (Cal/g)	Representation %	CV Contribution (Representative % * CV)	Calculated avg CV of heterogenous mix (kCal/kg)
1	LDPE	5,876.51	14.14	831	4,022
2	Polypropylene	4,743.95	9.09	431	
3	Multi-layered plastic	7,156.64	11.11	795	
4	Fines and inerts	120	21.21	25	
5	Textiles	5,000.00	37.37	1,869	
6	others	1,000.00	7.07	71	

The calorific value of SCF shows a notable increase, primarily attributed to a reduction in the inert fraction. This shows an improvement in the energy content of SCF, making it a more desirable and effective component for various applications, such as waste-to-energy processes or other combustion-based systems.

BANDHWARI DUMPSITE GURUGRAM



Age of the dumpsite **14 years**

Total dumpsite area **29 acres**

Accumulated waste quantity **45 lakhs tonnes** (32 lakhs tonnes legacy waste + 13 lakhs tonnes fresh waste)

Dumpsite remediation **Ongoing**

Legacy waste treated so far (October, 2023) **24 lakh tonnes**

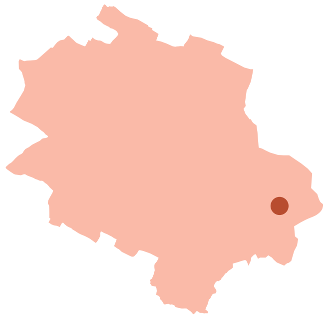
Legacy waste to be remediated (October, 2023) **21 lakh tonnes**

Waste utilization*

Legacy waste treatment and disposal cost **Rs 700 per tonne**

Percentage of segregated combustible fraction **15-20**

*Fine soil-like material as a filler in low-lying areas. RDF to be used in waste-to-energy plant.



Managed by the Municipal Corporation of Gurugram (MCG), Bandhwari dumpsite is spread over a constrained land area of 29 acres. With 35–40 lakh metric tonnes of waste, it is a high-density waste dump. The steep 40-metre-high dump hill is at an incline of over 45 degrees, making it dangerously unstable.

More than four leachate collection ponds were seen on the site, which were all flooded with toxic black leachate. Recent rains had deteriorated the conditions of the area even further. Puddles had formed on the roads and the waste was stinking to high heavens due to the high moisture content. The workers seemed to be working in hazardous conditions bereft of safety equipment.

The waste collected at this site is a mixture of different types, including organic, plastic and hazardous waste. The daily influx of mixed waste from Gurugram and Faridabad is reported to be 1,700 tonnes. The dumpsite has been operational since 2009. It has been causing significant environmental harm across the Gurugram-Faridabad border.

MCG has involved five contractors to accelerate the ongoing remediation process. About 10,000 tonnes of waste is remediated daily, as reported by the site-engineer, using the biomining process.

Trommels, air-density separators and magnetic separators were seen functioning at the site. These separators sort-out RDF from inerts, fine materials

Collection of samples from Bandhwari dumpsite

and metals. Samples of bio-mined SCF were collected from the site. The SCF samples were wet due to recent rains, which showed that they hadn't been properly stored under a shed.

In order to explore the potential of SCF as a sustainable alternative to fossil fuels, samples were collected from different parts of the dumpsite to be analysed for their composition and calorific value.

Composition and characterization of SCF at the Bandhwari dumpsite

Compositional analysis of SCF offers valuable insights into the diverse composition of the waste stream. Among the identifiable components, carry bags made from low-density polyethylene (LDPE) constitute a significant portion, comprising 29 per cent of the SCF. This indicates the prevalence of single-use plastic carry bags in the waste stream, highlighting the need for targeted interventions to address plastic pollution. Additionally, the presence of multi-layered plastics (14 per cent), textiles (15 per cent), and various other materials (19 per cent) signifies the complexity of the waste mix, emphasizing the importance of tailored strategies for effective recycling and resource recovery.

Moreover, the relatively low percentages of fine materials and inerts (8.5 per cent), leather and rubber (0.7 per cent), and foam (2 per cent) suggest a potential for valuable material recovery within the SCF. Proper segregation and treatment of these fractions can contribute to the reduction of landfill volumes and the promotion of a more sustainable waste management system.

Overall, the detailed compositional analysis serves as a crucial foundation for implementing targeted waste management practices, fostering circular economy principles, and minimizing the environmental impact of waste.

Graph 4: Composition of SCF obtained from the Bhandwari dumpsite

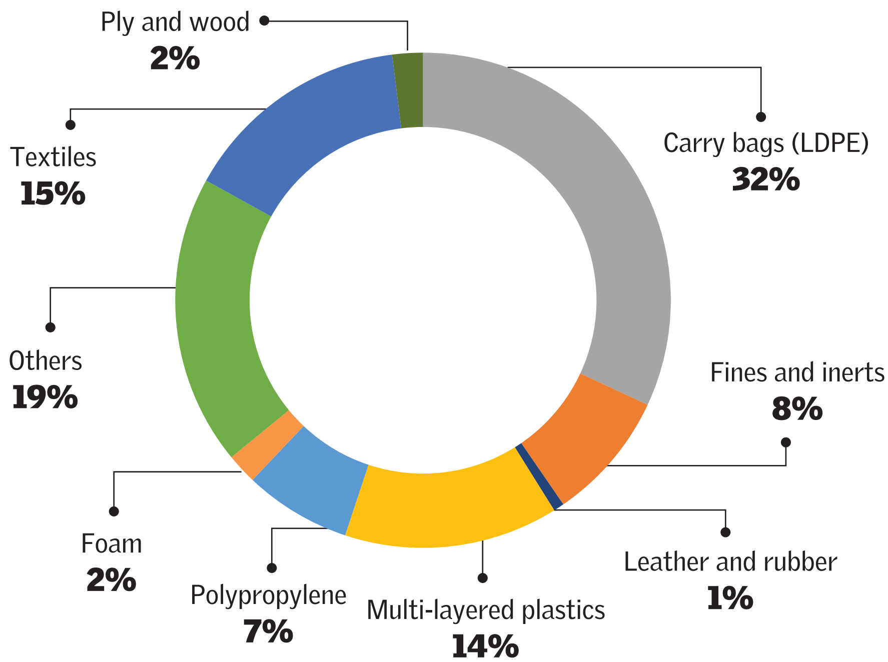
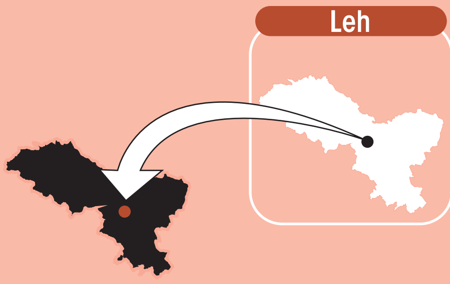


Table 5: CV estimation of SCF obtained from Bhandwari dumpsite

Sample type	Calorific value (Cal/g)	Representation %	CV Contribution (Representative % * CV)	Calculated avg CV of Heterogenous mix (kCal/kg)
LDPE	5,876.51	33.68	1,979	4,383
Polypropylene	4,743.95	7.37	350	
Multi-layered plastic	7,156.64	14.74	1,055	
Fines, Inerts	120	8.42	10	
Textiles	5,000.00	15.79	789	
Others	1,000.00	20.00	200	

BOMBGARH DUMPSITE
LEH



Age of the dumpsite **>25 years**

Total dumpsite area **28.4 acres**

Accumulated waste quantity **1,50,000 cum**

Dumpsite remediation **Ongoing***

Legacy waste treated so far (October, 2023) **1,50,000 cum**

Legacy waste to be remediated (October, 2023) **10,000 tonnes of RDF needs to be disposed of**

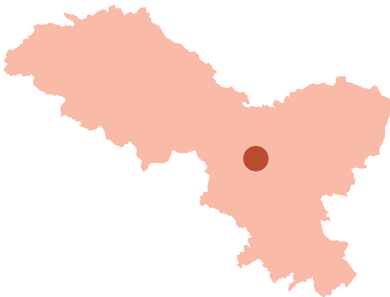
Waste utilization **Soil used for landfilling. Rocks sold by the contractor**

Legacy waste treatment and disposal cost **Rs 800 per tonne#**

Percentage of segregated combustible fraction **15**

*Treatment and segregation is completed but tendering for the procurement of incinerator for disposal of SCF is in process.

Only for segregation and treatment and disposal of inerts. RDF disposal needs to be done.



The Bombgarh dumpsite in Leh is currently non-operational for fresh waste disposal. Instead, fresh waste is being directed to a material recovery facility (MRF) situated at a different location. At the dumpsite, efforts are underway for the bioremediation of legacy waste. The dumpsite has been in existence for approximately 25 years, occupying a total land area in undulating terrain of 28.4 acres.

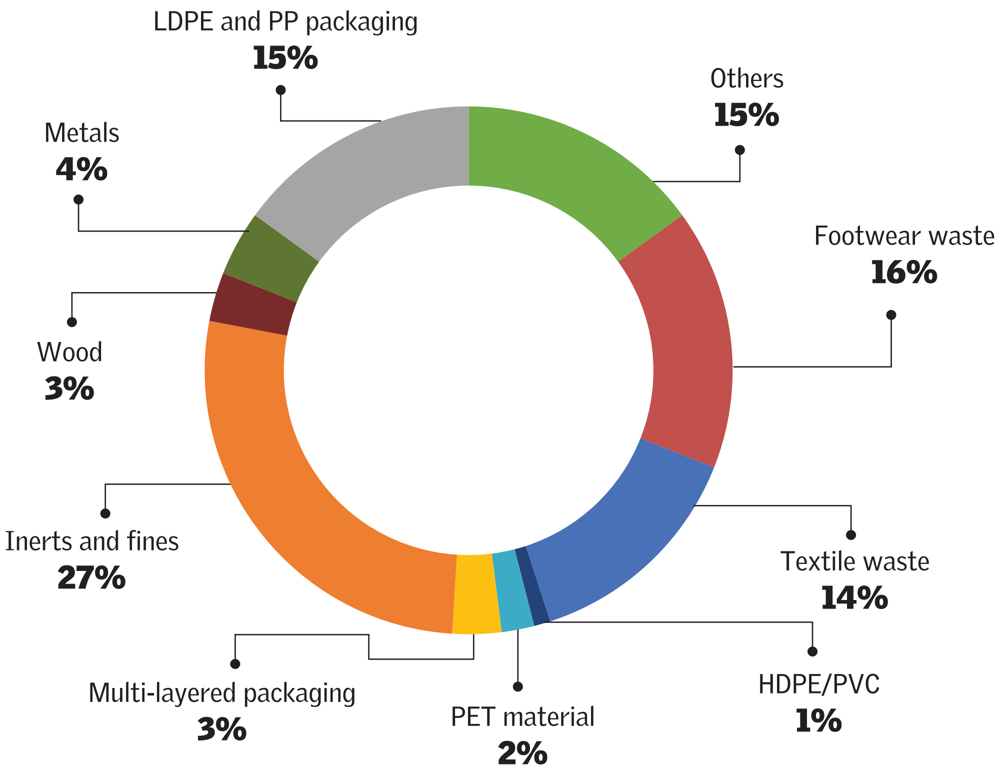
Until 2019, Leh lacked an adequate system for the treatment and scientific disposal of the city's waste. The continuous influx of tourists exacerbated Leh's waste management challenges, and in the absence of a proper treatment system, a significant portion of the waste was disposed of at the Bomgarh site.

In terms of recovered materials, approximately **15,000 tonnes of scrap combustible material** have been salvaged from the dumpsite. Nearby co-processing cement plants are Ambuja, ACC and Ultratech in Himachal Pradesh, along with ACC and Ambuja in Jammu.

Composition and characterization of SCF at the Bombgarh dumpsite

A representative sample of various fractions of SCF and fine inerts was prepared for analysing calorific value using a bomb calorimeter. The compositional analysis of the SCF sample reveals a diverse range of combustible components, each contributing different calorific values and percentages to the overall composition. It is important to note that LDPE and

Graph 5: Composition of SCF obtained from the Bombgarh dumpsite



*Others include sanitary waste, domestic hazardous waste and unidentified fractions

Table 6: CV estimation of SCF obtained from Bombgarh dumpsite in Leh

Sr. no.	Sample type	Calorific value (Cal/g)	Representation %	CV Contribution (Representative % * CV)	Calculated avg CV of heterogenous mix (kCal/kg)
1	LDPE and PP	7,991.12	17.05	1,362.12	2,969
2	Textiles and footwear	4,325.34	27.27	1179.64	
3	Multi-layered plastic	4,564.03	3.41	155.59	
4	Fines, Inerts	330.887	30.68	101.52	
5	Metals	0	4.55	0.00	
6	Others	1,000	17.05	170.45	

PP show a calorific value of 7,991.12 Cal/g, despite their relatively low percentage composition of merely 4.6 per cent.

Another substantial contributor is the category textiles (shoes, soiled clothes, etc.) constituting 27 per cent of the SCF with a calorific value of 4,325.34 Cal/g. This component not only possesses a significant representation percentage but can also contribute substantially to the overall energy potential, with a CV contribution of 1,179.64 Cal/g. The multi-layered plastic component, though having a lower percentage composition (3.4 per cent), makes a noteworthy contribution to the overall calorific value (4,564.03 Cal/g).

In contrast, the fines and inerts category, with a percentage composition of nearly 31 per cent, exhibits a lower calorific value of 330.887 Cal/g.

The estimated average calorific value of the heterogeneous mix (2,969 kCal/kg) signifies the collective energy potential of the SCF, offering valuable insights for potential energy recovery applications. These findings represent the importance of a detailed compositional analysis in optimizing legacy waste management strategies, particularly the disposal of SCFs, specifically in the context of the Leh dumpsite, guiding efforts towards efficient resource recovery and environmentally conscious disposal practices.

3. Available disposal/ treatment options for SCF

- **Thermal treatment technologies are typically used for legacy waste SCF disposal because the recovered materials typically do not contain any recyclable materials.**
- **There are around 80 cement co-processing plants in the country with a cumulative capacity of 116 lakhs tonnes per annum.**
- **As per CPCB's EPR portal, there are around 30 waste-to-energy plants with a cumulative capacity of 36 lakhs tonnes per annum.**

Treatment of legacy combustibles: Why only thermal treatment?

Thermal treatment technologies are primarily used for the treatment of plastic waste and other combustibles recovered from legacy waste dumpsite mining processes. These technologies include waste-to-energy, co-processing, pyrolysis and similar methods. The rationale behind this approach is that the recovered materials typically do not contain any high value plastics or recyclable plastics.

Our research has substantiated this theory, revealing that almost all the plastics retrieved during the biomining process are not suitable for recycling (mechanical recycling). It is important to note that a substantial portion of recyclable plastics is collected by informal waste-pickers and diverted from ending up in places like landfills or dumpsites, thus contributing to reducing environmental pollution and conserving resources.

The SCF often contains significant levels of contamination, rendering it unsuitable for various gainful applications. Given these limitations, the most viable course of action for these low-quality plastics and other combustibles, following a certain degree of treatment involving segregation and sorting, is to harness their considerable calorific value. This can be achieved through energy recovery or their use as an alternative fuel source, making it the most practical and sustainable option available.

In summary, the use of thermal technologies is imperative due to the lack of recyclable plastics and the high contamination levels in the recovered materials, with energy recovery or alternative fuel applications serving as the most viable alternatives.

Cement co-processing plants

As per the Basal Convention, a variety of wastes including industrial wastes and plastics get disposed of in an environmentally safe and sound manner through the technology of co-processing in cement kilns. Different kinds of hazardous and non-hazardous wastes including plastic wastes can be utilized as alternative fuel and raw materials (AFRs). During the usage of plastic wastes in cement kilns as AFRs, the material and energy value present in them gets fully utilized. In this way, they can act as replacement for conventionally used fossil raw materials and fossil fuels.

The Environment (Protection) Third Amendment Rules, 2016 were included in Schedule 1 of the Environment (Protection) Rule, 1986 to regulate the co-processing of plastic waste in cement kilns. Thanks to the amendment, co-processing is now an accepted waste management technique for SCF. This means that it would be acceptable to replace natural resources and fossil fuels in a controlled way and to use any waste as a raw material or energy source during the heating stage of the cement manufacturing process.

Cement kilns need a lot of energy to run, but because they operate at high temperatures—roughly 1,400°C and above—the waste is destroyed and no residue is left behind, which gives them an inherent advantage in co-processing. Thus, if it satisfies the emission and residue requirements in the trial run, employing plastic waste to burn as fuel during the heating stage of the clinker is advised. This can lessen the need for conventional fuels like coal and contribute to the reduction of plastic waste.

Co-processing is a type of recycling, however there are various ways to recycle or reprocess recyclable plastic trash. According to the guidelines in the Plastic Waste (Management) Rules, only non-recyclable plastic waste—that is, single-use plastic—may be co-processed in cement kilns. As a result, only non-recyclable plastic trash is used as AFR in cement kilns.

Every cement plant is required to have a separate feeding arrangement for undertaking co-processing of AFRs. In case it already has one on the calciner or kiln inlet, then the same can be utilized for plastics as well. The feeding facility shall also be equipped with a lab to carry out measurements of the calorific value, ash content, moisture content and chloride content.

It is important to note that the Solid Waste Management Rules, 2016 mandate industrial units to replace at least 5 per cent of their fuel requirement by refuse derived fuel (RDF). Some cement industries in India are already successfully using RDF substitute for fossil fuels. However, there are limited number of cement industries accepting SCF recovered from dumpsites and huge cost is incurred in its transportation. Even if there is potential for utilization, there is unavailability of expensive additional infrastructure required which is critical for co-processing of SCF recovered from biomining.

One of the critical factors responsible for limited usage of legacy combustibles in cement factories is the lack of trust in RDF quality. The primary objective of cement plants is to produce cement without compromising the quality and not to be part of an MSW management system. The quality of RDF (recovered from biomining of legacy waste dumpsites) is typically compromised due to high moisture content and high ash content. Cement plants have also expressed concerns regarding high chlorine content in RDF and inconsistent calorific values due to which they have to use this material by adding other alternative fuel like biomass by incurring additional cost.

Besides, the high cost of transportation is something to worry about. As per the CPHEEO guidelines, the transport cost for SCF/RDF up to 100 km from the cement plant shall be borne by the cement plant. However, beyond 100 km, the cement plant can transport at its own cost or the cost can be borne by ULBs as mutually agreed upon by the parties.

On the contrary, on ground the transportation cost is borne by the ULBs irrespective of the distance. In fact, in the hilly and remote areas, ULBs are struggling to dispose of the combustibles recovered from legacy waste dumpsites. For instance, Leh Municipal Committee is currently remediating their legacy waste dumpsites but the SCF recovered is waiting for final disposal (nearly 300–400 trucks containing SCF). Since the nearest cement co-processing units are situated in Himanchal Pradesh, Bihar and Rajasthan, transportation cost is huge and many of the co-processing facilities are not willing to accept the SCFs.

It is therefore extremely important to create an enabling ecosystem to address standardization of RDF quality, fix an appropriate price structure, lower transportation cost and provide standard documentation for increasing the gainful utilization of RDF by industries.

Other energy-intensive industries (other than co-processing industries) need to redesign their infrastructure for pollution control and replace fossil fuels with SCFs.

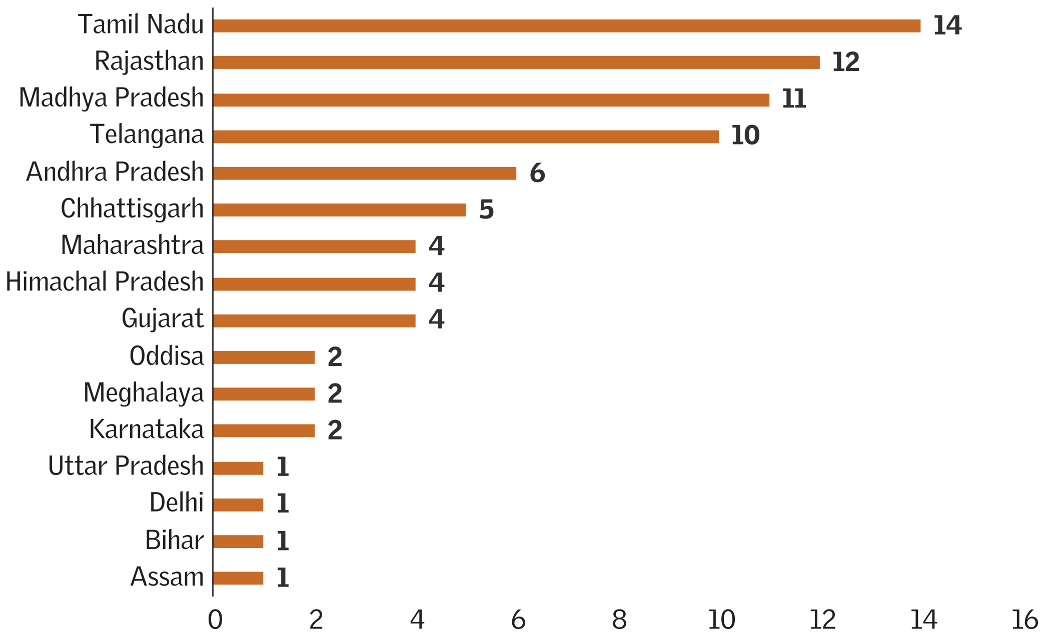
In addition, standards for RDFs need to be enhanced for better acceptability. The Central Public Health and Environmental Engineering Organisation (CPHEEO) under Ministry of Housing and Urban Affairs (MoHUA) in 2018 recommended the Ministry of Environment, Forest and Climate Change (MoEFCC) to amend the Solid Waste Management Rules, 2016. However, as of today no steps have been taken.

Status of cement co-processing in India

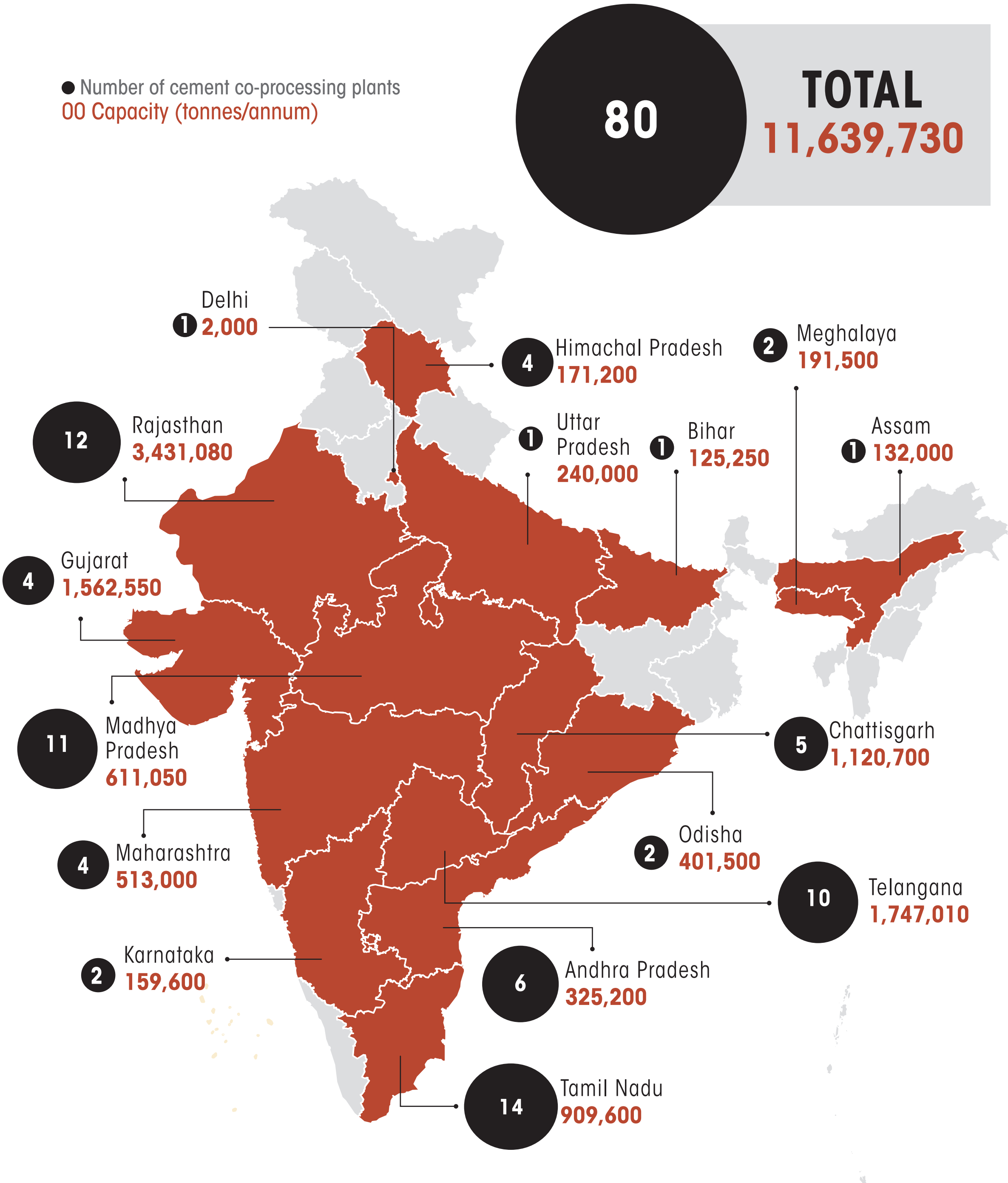
The distribution of cement co-processing plants across various states in India reflects the diverse regional pattern. With a total of 80 co-processing plants and a cumulative capacity exceeding 11.6 million tonnes per annum, it highlights the significant role of these facilities in contributing to scientific disposal of SCF across the nation. With Rajasthan leading the way with 15 such plants, followed closely by Madhya Pradesh and Tamil Nadu with 11 and 14 plants respectively as depicted in the Central Pollution Control Board's (CPCB) extended producer responsibility (EPR) portal. The states of Telangana and Andhra Pradesh each host 11 plants, emphasizing the geographical spread of these environmentally conscious initiatives.

The presence of a notable number of plants in Gujarat, Maharashtra, and Karnataka, with five to six plants in each, indicates a concerted effort in these regions to adopt cement co-processing to address waste challenges while

Graph 6: State-wise distribution of cement co-processing plants in India



Map 1: State-wise capacity of co-processing plants in India



Source: Compiled from the CPCB's EPR portal as on 20 August 2024

contributing to the circular economy. Additionally, the distribution of plants in states like Chhattisgarh, Himachal Pradesh, Odisha, Assam, Bihar and Meghalaya, though with a smaller count, signifies a broadening recognition of the potential of co-processing in diverse environmental and economic contexts.

However, the absence of data for certain states and Union Territories including Haryana, West Bengal, Jharkhand, Punjab, Uttarakhand and Kerala prompts consideration of the regions that may have not registered their cement co-processing plant on CPCB's EPR portal. It could be essential for those regions to explore and potentially adopt such sustainable practices, considering the environmental benefits and resource utilization that co-processing offers, particularly for disposal of legacy combustibles recovered from dumpsites.

Benefits of co-processing of waste in cement kilns

Cement manufacturing with co-processing is an innovative and sustainable approach to producing cement that reduces the environmental footprint associated with traditional methods. In traditional cement production, raw materials like limestone and clay are heated in kilns at extremely high temperatures, resulting in significant energy consumption and carbon emissions. Co-processing, on the other hand, integrates the use of alternative fuels and raw materials into the production process.

Co-processing involves carefully selecting alternative materials such as fly ash, slag or waste products from other industries, and substituting them for traditional raw materials. Similarly, fossil fuels are partially replaced with alternative fuels derived from sources like municipal solid waste, tires, biomass, plastics and even hazardous waste. These substitutions aim to reduce the environmental impact and enhance the sustainability of cement production.

Moreover, co-processing aligns with India's sustainability goals, as it promotes responsible resource utilization and waste management. It encourages cement manufacturers to conserve valuable fossil fuel resources by substituting them with plastics, thus further reducing carbon emissions in the long term. Additionally, stringent regulatory oversight and emissions control measures ensure that the co-processing of plastic waste complies with environmental standards, contributing to lower emissions from the cement industry.

The advantages of co-processing are manifold. First, it offers substantial environmental benefits by reducing the consumption of natural resources and minimizing carbon emissions. Additionally, it provides a more energy-efficient and cost-effective alternative to traditional fossil fuels. Furthermore, co-processing aids in the responsible disposal of industrial and municipal waste, reducing the burden on landfills. Cement kilns, which are integral to this process, are highly effective co-processors due to their high-temperature environment, ensuring the safe disposal of hazardous waste and the complete utilization of alternative materials. Stringent emissions control and air quality standards are maintained to ensure the safety and sustainability of the process.

However, co-processing is not without its challenges and concerns. Careful selection and treatment of alternative materials are vital to prevent contamination and maintain the quality of cement. Regulatory compliance and environmental monitoring are essential to guarantee the process's safety and environmental sustainability.

In terms of broader impact, cement manufacturing with co-processing aligns with several Sustainable Development Goals, notably responsible consumption and production (SDG 12) and climate action (SDG 13). This innovative approach plays a pivotal role in the cement industry's ongoing efforts to promote sustainability, reduce its carbon footprint, and contribute to waste management and resource conservation on a global scale.

How does a cement co-processing plant work?

The process of producing cement includes extracting and crushing raw materials (mainly limestone and clay); blending them to create raw meal; calcining the mixture in a rotary kiln; cooling the resulting clinker; mixing it with gypsum; and finally milling, storing and packaging the finished cement.

1. Quarrying and grinding of raw materials

Raw materials like limestone, clay and shale are extracted from quarries. The extracted materials are crushed and ground into a fine powder.

2. Homogenization

After the raw grinding process, the raw meal or slurry needs additional blending/ homogenization for optimal consistency before being fed into the kiln. The feed process is carefully controlled to maintain the desired mixture inside the kiln.

3. Preheating

The basic chemistry of the cement manufacturing process begins with the decomposition of calcium carbonate ($CaCO_3$) at about 900 °C to calcium oxide (CaO, lime) and liberated gaseous carbon dioxide (CO_2); this process is known as calcination.

4. Fuels: Storage and preparation

Fuels, both conventional and RDF, are pre-processed by pulverizing and drying for feeding into the kiln with suitable combustion properties and efficient heat generation.

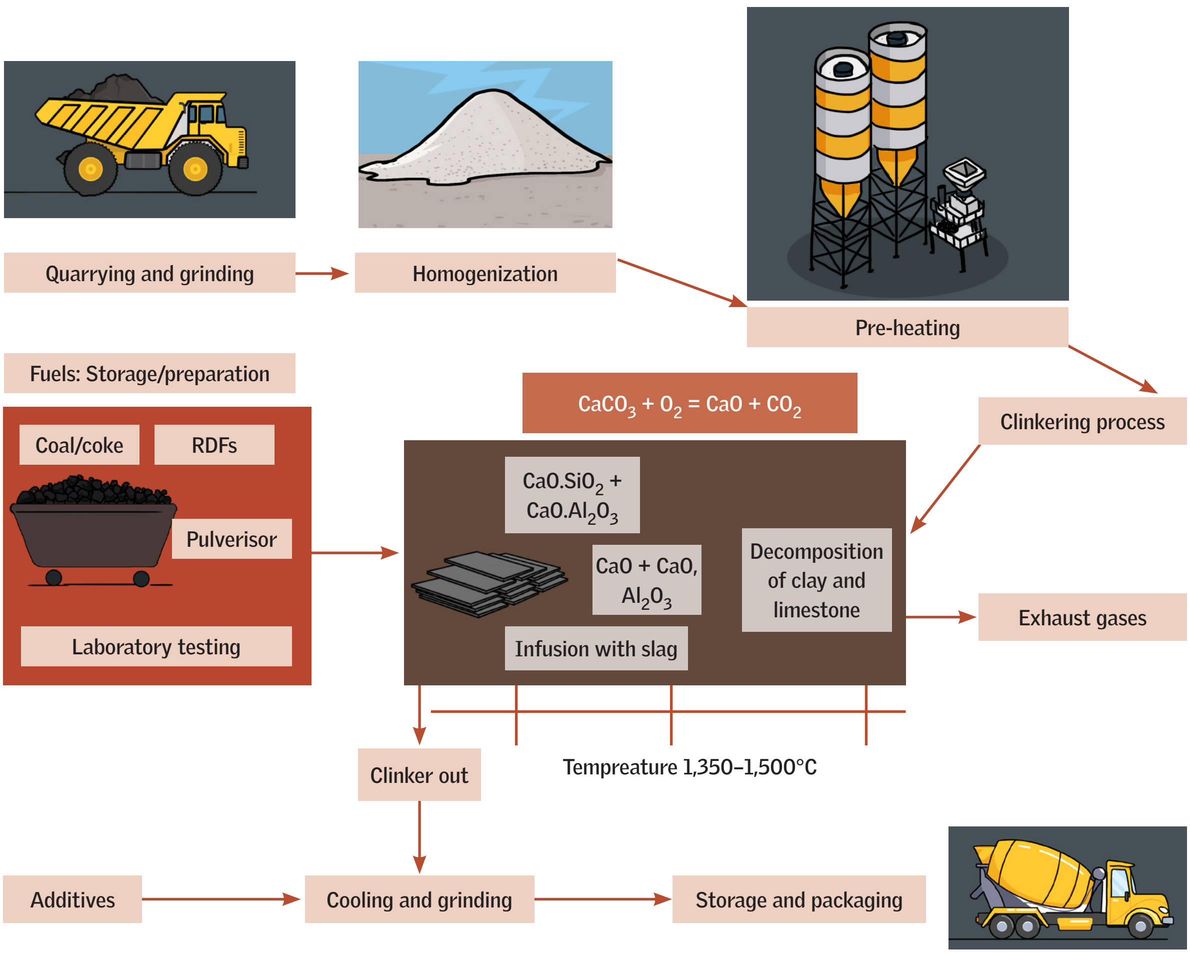
Pre-processing of SCFs/RDFs

- Pre-processing of SCFs/RDFs requires quality assessments for calorific value, moisture content, chlorine content, inert and heavy-metal content.
- The waste materials are introduced into the cement kiln along with the traditional fuel sources, such as coal or petcoke, through a controlled feeding system.

5. The clinkering process with kiln-firing

In a rotary kiln, the preheated material undergoes clinkering, involving high-temperature (typically 1,400–1,500 °C) reactions between calcium oxide, silica,

Figure 4: Process of cement manufacturing



alumina, and ferrous oxide to form the calcium-based compounds that make up the clinker. After combustion of the fuels, the main ash constituents of silica and alumina compounds (may contain trace metals) combine with the raw materials to become part of the clinker.

RDF inside kiln

The waste materials, along with the traditional fuels, are combusted in the kiln. The high temperatures inside the kiln cause the raw materials and waste to react, forming clinker, which consists of *fused materials.*

6. Cooling and grinding

The clinker is cooled down using air or water to a suitable temperature. The cooled clinker is finely ground with gypsum and other additives to produce cement.

7. Storage and packaging

The finished cement is stored in silos and then packaged in bags or bulk for distribution and sale

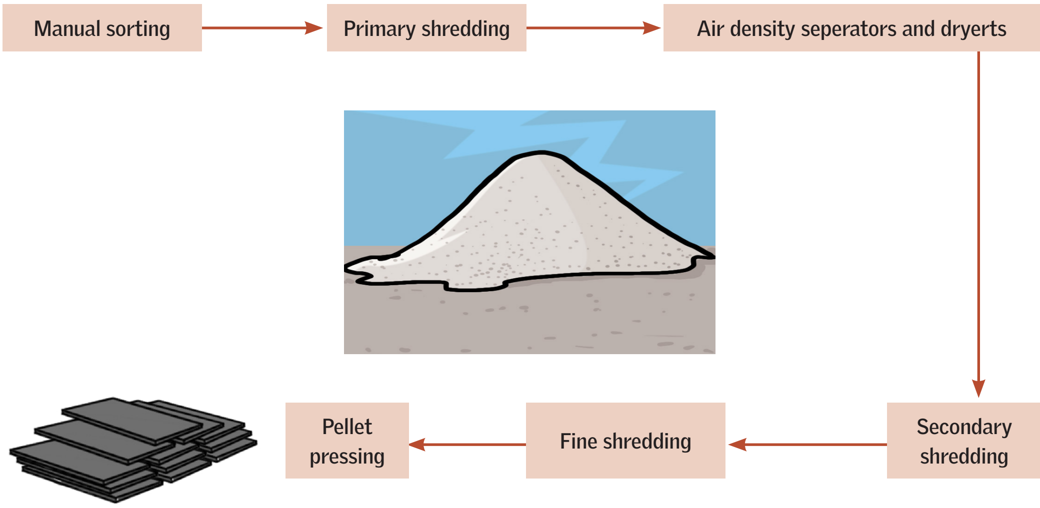
Process involved in an RDF plant

1. **Manual sorting:** In recycling facilities, manual sorting involves workers physically handling waste materials to identify and separate recyclables from non-recyclables and contaminants. Workers manually pick out recyclable materials like paper, cardboard, plastics, glass and metals. They may sort them further into different categories for more efficient recycling.

2. **Primary shredding:** Primary shredding is a mechanical process used in waste management and recycling to reduce large combustible materials into smaller particles, typically with a size of less than 100 mm. The goal of primary shredding is to prepare materials for further processing, combustion or disposal in a more manageable and efficient form. This process is particularly important for combustible waste materials, such as wood, paper, cardboard, plastics and other items that can be used as fuel sources or converted into energy.

3. **Separating and drying combustibles from bulky inerts by air density separators:** This is a sophisticated waste processing technique designed to separate different types of materials based on their density and size. This method is commonly employed in recycling centres to extract combustible materials like paper, plastics and textiles from non-combustible materials such as rocks, glass and metals. The principle behind the separation is that materials with

Figure 5: Fuel preparation (RDF preparation at cement plants)



different densities respond differently to the upward air current. Lightweight, combustible materials like paper and plastics are lifted and carried away by the airflow, while heavier, non-combustible materials such as metals and glass fall down due to their higher density.

4. **Secondary shredding:** This step further reduces the size of shredded materials, typically to a size of less than 50 mm. This finer shredding process is often used to prepare waste materials for various applications, including recycling, composting or as feedstock for waste-to-energy facilities. It helps create a more uniform and manageable material size that is suitable for specific industrial processes and applications.

5. **Fine shredding:** Reducing size after secondary shredding.

6. **Pellet pressing:** Pellet pressing, also known as pelletizing, is a process that transforms fine or powdery materials into compact, cylindrical pellets. This process is widely used in various industries, including waste management, to create manageable, transportable and storable materials. The concept of pelletizing involves compressing loose or powdered materials into dense pellets with the use of pressure and, in some cases, heat. Pellet pressing offers advantages such as easy storage and transportation, efficient material handling, and improved combustion or utilization characteristics. It contributes to sustainable waste management, energy production and resource utilization in multiple industries.

Factors affecting co-processing in cement kilns

Qualitative factors: Compositional factors affecting quality of RDFs

1. **Moisture content:** Moisture content affects the process of thermal utilization and compaction of RDF. High moisture content increases weight for transportation and has an inverse effect on calorific value. Also, humidity inside the kiln should not exceed 15 per cent.[6] As per CPHEEO, the desired moisture content of the RDF should be less than 20 per cent. However, moisture content of less than 15 per cent is recommended to avoid clogging of the rotary valves and pneumatic lines.[7]

2. **Chlorine content:** As per CPHEEO, chlorine content should preferably be less than 0.7 per cent. The presence of chlorides in RDF could be in the form of PVC and NaCl. The burning of RDF with high chlorine content could be detrimental for the cement clinker since it leads to:
   - Formation of metal chlorides (also with heavy metals) causing high temperature corrosion to the kiln furnace (made up of ceramic material).
   - Formation of HCL at relatively low temperatures in the kiln (700 °C to 1,000 °C). HCl vapours and chloride in any forms are toxic to humans).[8]

3. **Ash content** constitutes oxidized products that contribute to silica and alumina rich slag.
   - Most of the deposition gets fused with the clinker.
   - However, ash composition may cause fouling depending upon viscosity, SiO_2/Al_2O_3 ratio and acid/base ratio, reducing energy efficiency.[9] Efficient combustion will ensure lesser ash content and higher volatile content.

4. **Sulphur content**
   - SO_2 released during combustion has relatively lower concentration since it gets absorbed by alkaline metals present in fuel ash to form alkali sulphates.[10]

DESIRABLE PARAMETERS FOR CO-PROCESSING

- Moisture, preferably <20%
- Size, 2D <120 mm, 3D <70 mm
- Chlorine content <0.7%
- Sulphur content <2%
- Calorific value >3,000 kcal/kg

Source: CPHEEO Manual

- Resulting formation of alkali sulphate creates a reducing atmosphere enabling the formation of corrosive gases like CO and H_2S.

5. **Calorific value**
   The calorific value of segregated combustible material plays a pivotal role in determining its applicability for use in cement co-processing units and waste-to-energy plants. The calorific value, representing the amount of energy released upon combustion, directly influences the efficiency and effectiveness of these processes. In cement co-processing units, materials with higher calorific values contribute more heat during combustion, enhancing the overall energy balance of the system. This, in turn, reduces the need for traditional fossil fuels, promoting sustainable practices and mitigating environmental impacts.

   In the context of waste-to-energy plants, the calorific value becomes a critical factor in optimizing energy generation. Materials with higher calorific values yield more energy per unit of mass, making them desirable for efficient electricity or heat production. Additionally, higher calorific values contribute to increased combustion temperatures, positively impacting the overall efficiency of energy recovery systems.

   Conversely, materials with lower calorific values may require supplementary energy sources in these processes, potentially affecting the economic viability and environmental sustainability of such initiatives. Therefore, a thorough understanding of the calorific value of segregated combustible materials is essential for making informed decisions regarding their utilization in cement co-processing units and waste-to-energy plants, ensuring maximum efficiency and minimal environmental impact.

Physical factors

1. **Temperature:** One of the key factors affecting the successful co-processing of plastics in cement production is temperature. The temperature inside the cement kiln must be rigorously maintained above 1,400°C. This high temperature is critical for several reasons.

   Firstly, it ensures the complete combustion of plastic waste, breaking down complex hydrocarbons into simpler molecules. This not only minimizes the release of harmful pollutants but also facilitates the production of clinker, a vital component of cement.

Secondly, the high temperature plays a pivotal role in the homogenization of materials within the kiln, ensuring consistent and high-quality cement production. Achieving and sustaining this temperature threshold is essential for the effective and environmentally responsible utilization of non-recyclable plastics in the cement manufacturing process.

What happens when the temperature falls below 1,000 °C?

- Chlorine in form of PVC, NaCl or chlorobenzenes can act as pre-cursor for the formation of dioxins and furans when RDFs are burnt at **low temperatures**, under reducing conditions.
- It also contributes to the formation of HCL at relative low temperature in the kiln (700 °C to 1,000 °C).

2. **Retention time:** Typically, traditional fossil fuels require retention time of 10 seconds, but fuels derived from wastes requires more time to be burnt.
   - Oxidizing/Reducing environments: Conditions inside kiln must be oxidizing. Reducing conditions can enable formation of CO, H_2S, dioxins and furans.

Table: 7: Comparative analysis of MSW-based RDF usage

	Parameters	SCF	RDF - Grade III	RDF - Grade II	RDF - Grade I
1	Intended use	Input material for waste-to-energy plant or RDF pre-processing facility	For co-processing directly or after processing with other waste materials in cement kilns	For direct co-processing in cement kiln	For direct co-processing in cement kiln
2	Size	Anything above 400 mm must be mutually agreed between ULB or SCF supplier and cement plants.	<50 mm or <20 mm depending upon use in ILC or SLC, respectively		
3	Ash – maximum permissible	<20 %	<15 %	<10 %	<10 %
4	Moisture – maximum permissible	<35 %	<20 %	<15 %	<10 %
5	Chlorine –maximum permissible	< 1.0 %	< 1.0 %	< 0.7 %	< 0.5 %
6	Sulphur – maximum permissible	<1.5	<1.5		
7	Net Calorific Value (NCV) in Kcal/kg (Average figure of every individual consignment)	> 1,500 KCal/kg net	> 3,000 KCal/kg net	> 3,750 KCal/kg net	> 4,500 KCal/kg net
8	Any other parameter	SCF – any offensive odour to be controlled	RDF – any offensive odour to be controlled	RDF – any offensive odour to be controlled	RDF – any offensive odour to be controlled

Source: Guidelines on Usage of Refuse Derived Fuel in Various Industries, CPHEEO, MoHUA, 2018

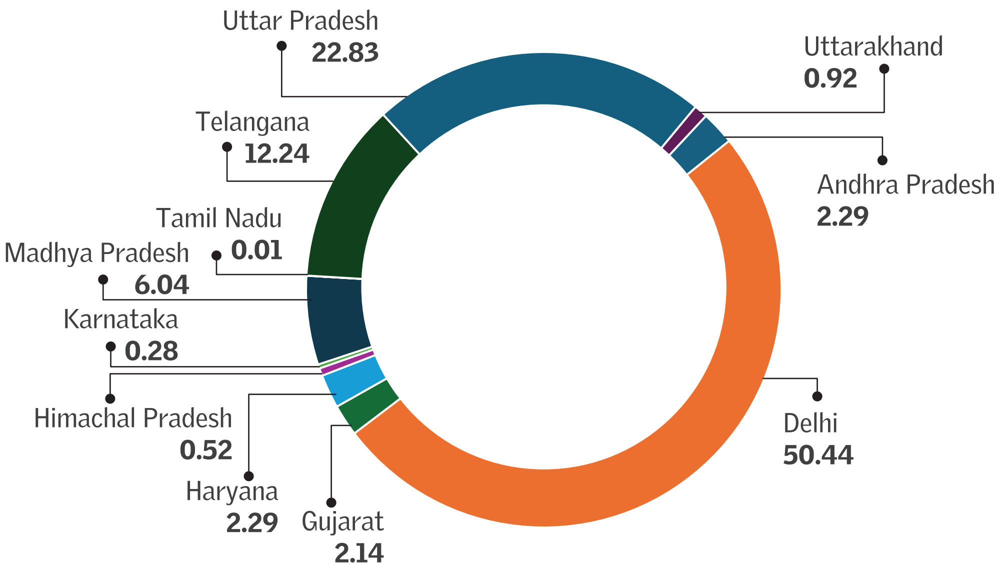
3. **Quantity of sorted combustible fraction**
4. **Feeding mechanism/infrastructure**
5. **Particle size:** In order to mix with coal, RDF should be pulverized to sizes of less than 400 mm.

Waste-to-energy (WTE) plants

Incineration is a process used in waste-to-energy facilities to recover energy from dry, combustible wastes, such as municipal solid waste (MSW), which has a calorific value of more than 1,500 kCal/kg. To meet the emission restrictions outlined in the Solid Waste Management Rules, 2016, pollution control devices, flue gas treatment and temperature regulation in the combustion chamber are used to manage pollutants released during incineration. Additionally, the facility has Online Emission Monitoring Systems installed, which are under the supervision of respective state pollution control boards (SPCBs).

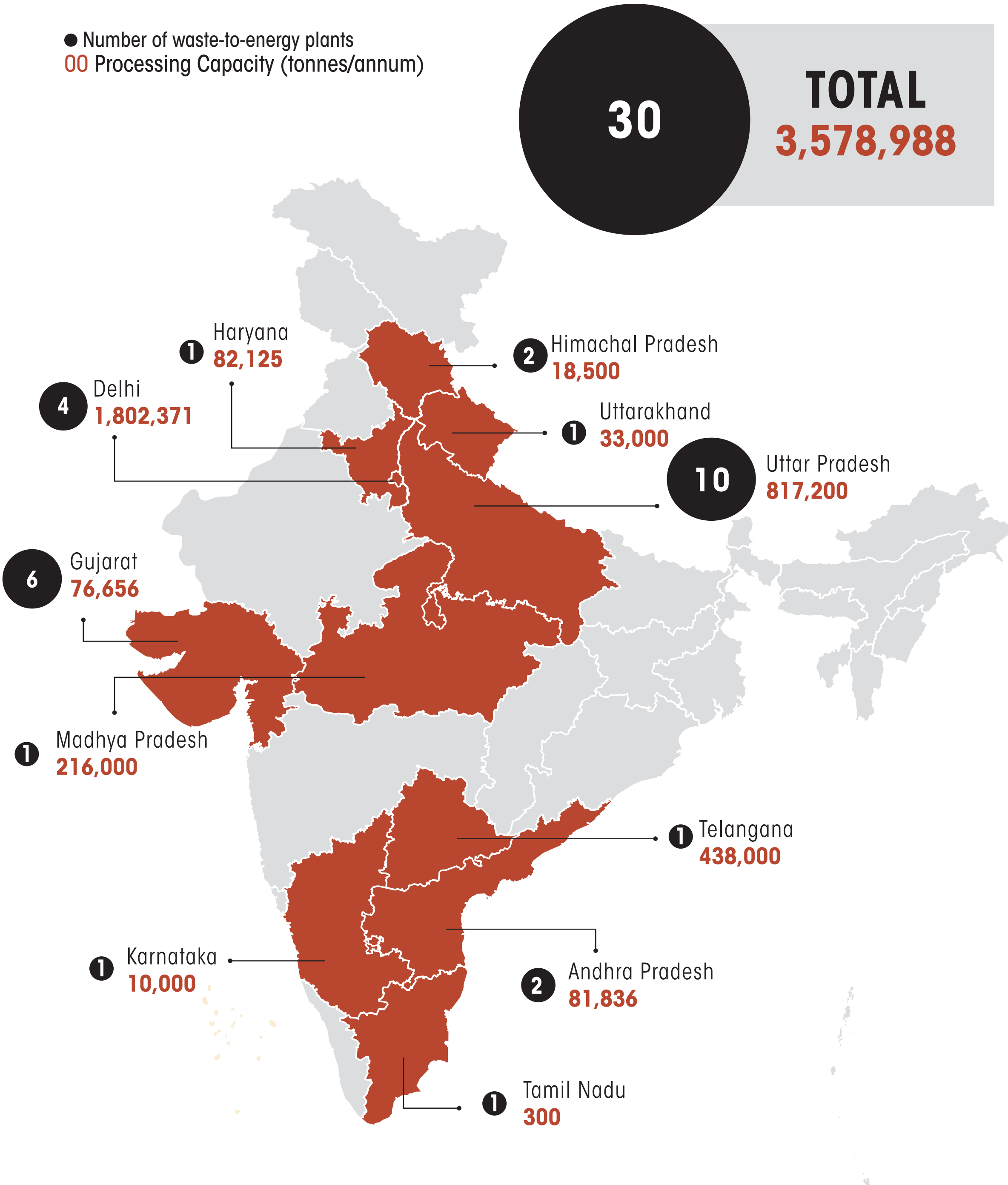
As per Ministry of New and Renewable Energy as on 18.02.2022, 11 plants with a total cumulative installed capacity of 132.1 MW for power generation from MSW have been set up in the country. These plants have a capacity of processing approximately 11,000 tonnes of MSW per day to generate electricity.

Graph 7: Percentage contribution of waste-to-energy plants in different states in India



Source: Compiled from the CPCB's EPR portal as on 20 August 2024

Map 2: State-wise distribution of waste-to-energy plants



Source: Compiled from the CPCB's EPR portal as on 20 August 2024

However, the data from CPCB's EPR portal highlights the distribution of these facilities across different states in India. The numbers indicate the count of WTE plants registered on CPCB's EPR potal in each state.

There are two WTE plants in Andhra Pradesh, while Delhi has four, and Gujarat leads with six plants. Haryana, Himachal Pradesh, Karnataka, Madhya Pradesh, Tamil Nadu, Telangana and Uttarakhand each have one. Uttar Pradesh, a populous state, boasts of four such facilities. In total, there are 30 WTE plants across these states with a cumulative capacity of 3.6 million tonnes.

WTE plants utilize various technologies to produce electricity or heat. The presence of these plants in different states reflects a commitment to sustainable waste management practices, aligning with the broader goal of minimizing environmental impacts associated with waste disposal.

Gujarat's notable count of six WTE plants suggests a strong emphasis on incorporating these technologies into its waste management framework. The higher numbers in Delhi and Uttar Pradesh align with the challenges posed by densely populated urban areas, where effective waste disposal and energy generation are critical concerns.

Incineration/Open burning

Open burning of plastics is a long-standing practice that is still common in most communities worldwide, particularly in developing and poor nations. Burning plastic waste in open spaces is a significant cause of air pollution. Plastics of various types make up around 12 per cent of most municipal solid waste, and 40 per cent of the world's waste is burnt.

In addition, the burning of plastic produces solid residual ash (a dark carbonaceous colour) and soot, which are airborne particle emissions. According to numerous studies, soot and solid residue ash have a high potential to harm human health and the environment, particularly when it comes to volatile organic compounds (VOCs), semi-volatile organic compounds (semi-VOCs), smoke (particulate matter), particulate-bound heavy metals (PAHs), polychlorinated dibenzofurans (PCDFs), and dioxins.

Downcycling of plastics

The recycling of plastic trash into materials that are less useful and of lesser quality than the original material is known as downcycling. Nevertheless, following recycling, recovered plastics cannot be used for the same purpose as other materials like glass and metal. This is typically the case because polymers eventually lose their fundamental features, such as mechanical integrity and optical clarity, making them unsuitable for their original usage. One way to recycle plastic is to turn it into artificial grass or plastic furniture. In general, downcycling results from mechanical recycling of plastics through heating and moulding processes. The material eventually becomes unsuitable for items with strict technical specifications.

In case of combustibles recovered from biomining of legacy waste dumpsites, attempts to convert them into useful recycled products such as furniture, bricks, etc. has not been adequately tried in India so far.

Upcycling of plastics

The act of converting discarded plastic materials into new materials or products seen to be of higher quality, such as artistic worth or environmental value, is called upcycling, also known as creative reuse. Toys for kids, Christmas trees, flower pots, bird feeders, garden sprinklers, green parking canopies, chandeliers, and more may be made from recycled plastic bottles. Articles made from waste plastic that undergo heating and remoulding during the repurposing process are downcycled since they can't be used in the strictest engineering applications over time. Through thermo-chemical procedures, waste single and mixed plastics have been successfully upcycled. One of these thermo-chemical processes that is now receiving a lot of interest is pyrolysis.

Pyrolysis

Pyrolysis is the term used to describe the thermal breakdown of plastic waste at various temperatures (300–900 °C) without oxygen to create liquid and gaseous fuel. When a source of energy, such as used plastic, is burned in an oxygen-free or low-oxygen atmosphere, it pyrolyzes instead of burning, creating a mixture of simpler hydrocarbons. Plastics are formed from tiny building blocks (monomers) by a process known as polymerization; this process is merely heat depolymerization. Pyrolysis turns old, waste plastics into valuable resources including fuel, monomers and other usable materials.

Types of pyrolysis

Slow pyrolysis

The gradual heating of the feedstock without oxygen is known as slow pyrolysis. The volatile components of the organic material partially evaporate instead of burning, leaving behind a substance called char that is mostly (usually 80 per cent) made

SOURCE: ZIGMA GLOBAL ENVIRON SOLUTIONS PVT. LTD.

Materials made from legacy waste plastics and metals up of carbon. In contrast to quick pyrolysis, which highlights the liquid result, slow pyrolysis emphasises the solid char as the principal product. The heating rate is maintained at 10 °C/s.

Fast pyrolysis

Fast pyrolysis produces large amounts of liquid fuel by quickly heating the feedstock to moderate temperatures (400–600 °C) with a short residence period (a few seconds). Fast pyrolysis creates an environment that maximizes the creation of liquid; the reactor is thought to run isothermally as a result. It is the approach used most frequently in research and actual pyrolysis of polymers. Heat transfer is maintained at 100 °C/s.

Flash pyrolysis

Ultra-fast or flash pyrolysis has a high heating rate and a quick thermal breakdown. The major byproducts of this type of pyrolysis are gases and bio-oil. The range of heating speeds is 100–10,000 °C/s, and residence periods are brief.

The Brihanmumbai Municipal Corporation (BMC) made a huge decision to treat 70 lakh tonnes of waste at the Mulund dumpsite after working on the Gorai dumping ground. However, hardly 20.27 lakh tonnes of waste has been treated in the last two years. The remaining waste, which totals more than 50 lakh tonnes, must be processed in the next two years, per the contract.

The Mulund dumping ground waste processing project was given a six-year contract in 2018, but it didn't begin until 2021 when the contractor obtained the necessary equipment and approvals from multiple authorities.

The problems with plastics separated from the waste still exist. BMC has now established two processing plants at the location in order to convert it into oil or pellets. One of the two units that the BMC has established is an RDF facility that will process 100 tonnes of SCF every day and turn it into pellets. In sectors like cement mills, the pellets can take the place of fossil fuels. Twenty tonnes of plastic will be treated daily at the pyrolysis facility. There are just a few cement companies that take SCF retrieved from dumpsites, despite the BMC being in negotiations with the cement and power sectors to accept the final products.

Gasification

The thermochemical process of turning a solid or liquid carbon-based substance (feedstock) into a combustible gaseous product (combustible gas) while using a gasification agent (another gaseous molecule) is known as gasification.
By using high temperatures, the thermochemical conversion modifies the chemical composition of the biomass. Through many heterogeneous reactions, the gasification agent enables the feedstock to be swiftly transformed into gas. The combustible gas comprises several impurities, including tiny char particles, ash and tars, as well as CO_2, CO, H_2, CH_4, H_2O, trace quantities of higher hydrocarbons, inert gases contained in the gasification agent, etc.

When a feedstock is partly oxidized by an oxidant gasification agent, direct gasification results. The energy needed to maintain the process's high temperature comes from oxidation processes. The process is known as indirect gasification and requires an external energy source if it doesn't use an oxidizing agent. Because it is simple to manufacture and raises the hydrogen concentration of the combustible gas, steam is the indirect gasification agent that is utilized the most frequently.[11]

Waste torrification or pelletization

RDF is the term used to describe the pelletization of municipal solid waste, which is the process of separating, crushing, mixing and hardening organic waste material with varying heat values to create fuel pellets or briquettes. The procedure removes moisture and inorganic components from the waste, condenses it or modifies its physical shape, and enhances its organic content. Depending on the quantity of organic matter in the waste as well as the additives and binder materials employed during the pelletization process, the calorific content of RDF pellets can range from 4,000 kcal/kg to 5,000 kcal/kg.

Torrification is a thermochemical process that involves the mild pyrolysis or partial carbonization of organic materials, particularly combustible solid waste or RDF at relatively low temperatures and in the absence of oxygen. The process can make the RDF more stable, reduce its moisture content, and improve its energy content, making it a more suitable and efficient fuel source for various applications, including combustion in energy-intensive industries and co-processing in cement kilns. This treatment can enhance the properties of RDF and make it a more sustainable and effective energy source.

An onsite RDF pelletization facility has been set up at the Mulund dumpsite in Mumbai. This facility is designed to transform SCF into high-quality pellets or upgraded RDF. The process begins with reducing the size of the combustible

RDF pelletization plant at Mulund dumpsite in Mumbai

Bales of legacy waste plastics used at Mulund dumpsite

Torrified combustibles derived from legacy waste dumpsites in Mulund, Mumbai

materials from 50 mm to 25 mm and eventually down to 10 mm. The materials smaller than 25 mm are separated using various shredding machines and trommels. Subsequently, the shredded combustible materials are further processed through a heating process, leading to the formation of pellets with a gross calorific value equivalent to approximately 5,500 Kcal/kg.

This facility essentially enhances the energy content and quality of RDF, making it a more efficient and sustainable fuel source for various applications, including co-processing in cement kilns or other combustion processes. The RDF pellets produced through this process offer a higher calorific value, making them a valuable resource for energy recovery and waste management.

It is important to understand that the RDF pelletization process has the potential to offer environmental benefits by reducing landfill usage and replacing fossil fuels with waste-derived energy. However, the environmental impact and pollution risks should be carefully managed through quality control, emission control technologies, and adherence to regulations to ensure a sustainable and environmentally responsible approach.

Extended producer responsibility (EPR) and corporate social responsibility (CSR)

EPR is a policy approach that places the responsibility of managing a product's end-of-life on the producer rather than the customer or local authorities. EPR requires manufacturers to handle the collection, recycling, or disposal of plastic items they release onto the market. The basis for EPR in plastic waste management was established in India by the Plastic Waste Management Rules, 2016. Under these regulations, manufacturers and brand owners that release plastic goods onto the market are required to set up a system for gathering and handling the plastic waste that is produced by their products. To guarantee that their products are disposed of and recycled properly, producers must collaborate with garbage collectors, recyclers and municipal authorities. They must also fulfil yearly goals for the collection of plastic waste. Making manufacturers responsible for the plastic garbage they make has been made possible in large part by this rule.

Since the Plastic Waste Management Rules were introduced, India's EPR implementation has advanced noticeably. Many businesses have adopted EPR practices, especially those in the fast-moving consumer goods (FMCG) industry. These businesses are taking action to gather and recycle plastics, frequently working with waste management corporations and non-profits.

But problems still exist. States and industries use EPR implementation differently. Some areas have poor EPR compliance, which results in a large amount of plastic waste going uncollected or poorly handled. Furthermore, regulatory agencies' oversight and enforcement of EPR compliance needs to be strengthened.

Use of CSR funds

CSR can serve as a pivotal funding mechanism to alleviate the substantial transportation costs incurred in transporting the SCF to cement co-processing plants in various cities. By establishing dedicated CSR funds, companies, especially those obligated under EPR, can allocate resources specifically for waste management initiatives. Collaborative efforts through public-private partnerships (PPPs) enable municipal bodies and private entities to pool resources, with CSR funds contributing significantly to covering transportation expenses. Cities can actively seek CSR grants earmarked for waste management projects, encouraging companies with a commitment to environmental sustainability to allocate funds to support the transportation and disposal of non-recyclable plastic waste in cement co-processing plants.

Moreover, CSR funds can be directed towards technology and infrastructure development, capacity building programs, research and development initiatives, and community engagement efforts—all of which contribute to reducing overall costs and improving the efficiency of waste management processes. Aligning CSR initiatives with company goals and ensuring transparent reporting and accountability in fund utilization further strengthens the impact of these collaborative efforts, fostering a sense of shared responsibility between the public and private sectors. This approach not only addresses financial challenges but also advances sustainable waste management practices, making them more viable and impactful across diverse urban landscapes.

4. Prayagraj model for RDF utilization

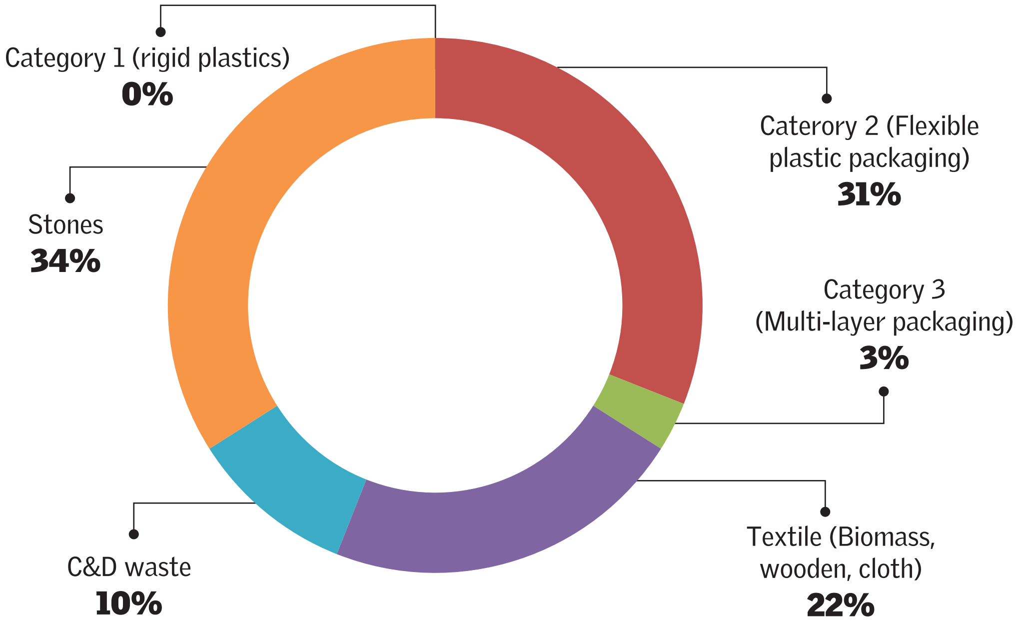
- **Prayagraj has currently adopted a unique EPR-based business model for co-processing of non-recyclable plastic waste**
- **This model has successfully created a win-win condition for all the stakeholders involved: ULBs; producers, importers and brand owners (PIBOs); and cement industries.**
- **A tripartite agreement was signed between Prayagraj Municipal Corporation, Karo Sambhav and Dalmia Cement (Bharat) Ltd to implement this model in Prayagraj.**

Many Indian cities face challenges in disposing of the RDF fraction recovered from biomining their legacy waste dumpsites, primarily due to the significant costs associated with transporting RDF from biomining sites to the nearest co-processing cement industry. In contrast, Prayagraj city in Uttar Pradesh has embraced a distinctive and sustainable business model for the scientific and cost-effective disposal of the RDF fraction recovered from the remediation of legacy waste dumpsites. The model has been very effective in reducing the cost of managing RDF.

The Department of Environment, Forest & Climate Change of the Government of Uttar Pradesh, in collaboration with GiZ India, has developed an "EPR-based Business Model for Co-Processing of Non-Recyclable Plastic Waste" currently in use in Prayagraj. This model's requirements are based on the PWM (Amendment) Rules, 2022. The initiative explores a mutually beneficial solution for ULBs, producers, importers and brand owners (PIBOs), and cement industries. It considers non-recyclable plastic waste in the context of EPR and addresses the end-of-life disposal of combustible materials through co-processing in cement kilns. As a result of this program, cement plants have already co-processed approximately 2,500 tonnes of non-recyclable plastic waste from Prayagraj.

Dalmia Bharat Limited has issued EPR certificates for the recycled plastic under the end-of-life disposal categories 2 and 3. Currently, three biomining agencies, namely BVG India, Hari Bhari, and Ecostan Infra, are operating at the Baswar dumpsite in Prayagraj.

Graph 8: Compositional analysis of SCF from the dumpsite in Prayagraj



The business model in Prayagraj encompasses the following key elements:
A. Linking plastic waste opportunities to EPR obligations: This approach associates the opportunities presented by these plastics with the necessity to fulfil EPR obligations of PIBOs.
B. Alternative fuel for cement industries: The business model facilitates the use of RDF as an alternative fuel source for cement industries.
C. Legacy waste disposal by Prayagraj Municipal Corporation (PMC): The model also addresses the disposal of legacy waste by the Prayagraj Municipal Corporation.

This business model has proven to be a mutually beneficial arrangement for all stakeholders involved.

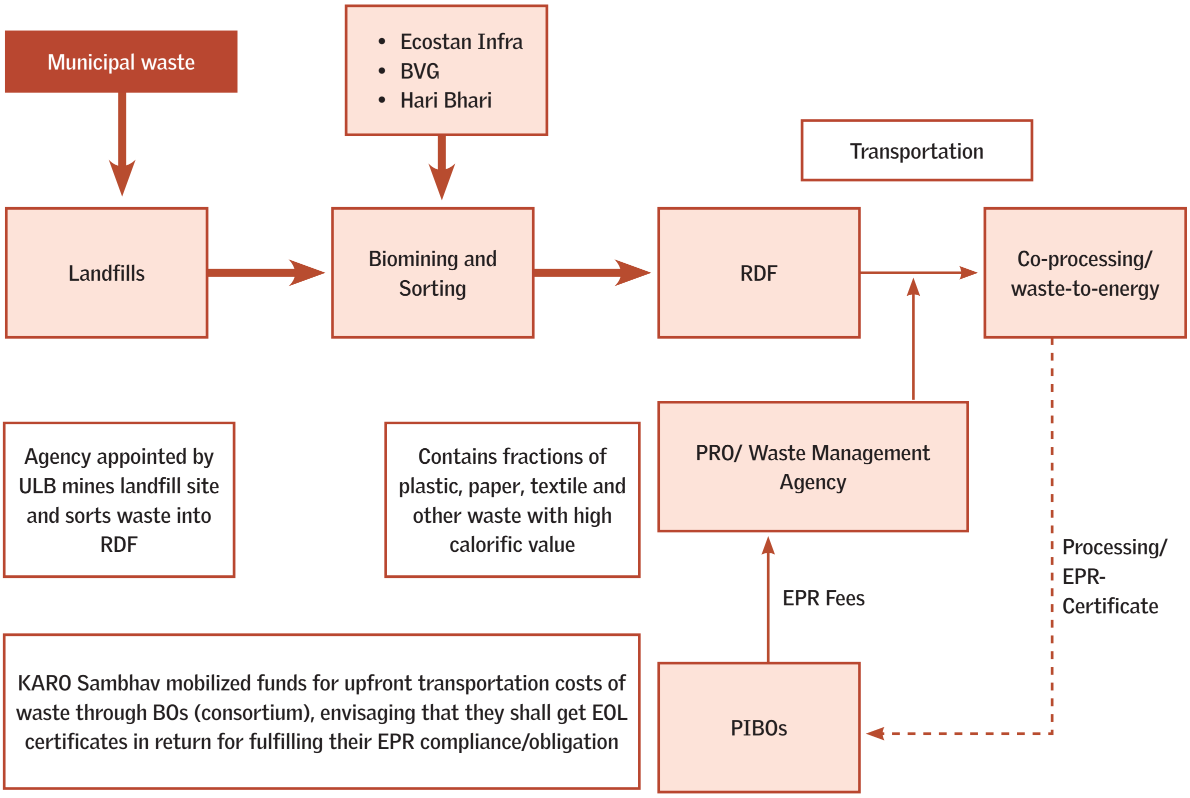
On 21 October 2022, a tripartite agreement was signed between Prayagraj Municipal Corporation, Karo Sambhav and Dalmia Cement (Bharat) Ltd to implement this model in Prayagraj. To achieve this, a compositional and characterization study of the legacy waste was conducted, involving the collection of samples from the site. This study aimed to determine the percentage composition of different components within the segregated combustible fraction in Prayagraj.

RDF disposal by Dalmia Cement:
- Till June 2023, potential for 488 MT EPR credit by co-processing RDF
- Till August 2023, potential for 1,479 MT EPR credit by co-processing RDF

Table 8: RDF disposed of in Prayagraj dumpsite

Total RDF disposed of since March 2023	Total RDF disposed of (to Dalmia Cement)
(Legacy) 32,733 tonnes	(Legacy) 14,790 tonnes
3,273 tonnes	1,479 tonnes

Figure 6: Prayagraj model for legacy combustible disposal



One significant challenge faced by this business model is the transportation cost of RDF to the co-processing plants. To surmount this obstacle, Karo Sambhav has agreed to bear the upfront transportation costs through a consortium, with funding provided by specific brand owners (PIBOs) who are obligated under EPR. In return for their support, the co-processing units will issue category 2 (flexible plastics) and category 3 (multi-layered plastics) certificates to the PIBOs who cover the transportation expenses.

Challenges

One of the significant challenges encountered in this model was the varying consistency in the quality of RDF. To maintain a consistent supply of RDF to the co-processing plants, it is crucial that the quality remains stable. However, this is a complex task as there is no way to determine the age of the biomined legacy waste, making it unpredictable to ascertain the quality of RDF it will produce. Additionally, it's challenging to predict the composition of fresh waste brought to the dumpsites on a daily basis.

Another challenge that arose was the lack of clear guidelines regarding the extent of financial support from the EPR consortium. It was unclear whether the consortium would support the system partially, fully, or if PIBOs would solely bear the transportation costs.

RDF undergoes three stages of processing before being transported to cement kilns. However, at the Baswar dumpsite, there was no distinct demarcation for RDF collection points. This resulted in a high likelihood of the RDF being mixed with inorganic materials, C&D waste, and biosoil once again during the loading process.

Opportunities and measures to improve RDF quality

- RDF separation in trommels and ballistic separators
- Daily clearing of C&D waste and biosoil in adherence with the guidelines set by the Central Pollution Control Board (CPCB)
- Clear demarcation for storing processed RDF separately from inert materials and contaminants
- Aligning the monitoring process with the standards of co-processing units
- Developing a standard mechanism to ensure the quality of RDF is maintained

Scale of replicability

The business model implemented in Prayagraj for the co-processing of non-recyclable plastic waste, with a focus on EPR and cement kiln utilization, holds potential for replication in other Indian cities. Key to its success is alignment with the PWM (Amendment) Rules, 2022, providing a regulatory framework that facilitates EPR obligations and waste management. The model's reliance on collaborative efforts among ULBs, PIBOs and cement industries is crucial for its effectiveness.

The presence of suitable infrastructure, such as cement kilns, and a commitment to waste characterization studies are prerequisites for adaptation. Addressing financial challenges, particularly transportation costs, requires innovative funding mechanisms, as demonstrated by Karo Sambhav's consortium. Public awareness campaigns and customization to local contexts, considering unique challenges and opportunities, are imperative for success. The model's replicability hinges on meticulous planning, stakeholder engagement, and a tailored approach to each city's waste management landscape.

In conclusion, while the Prayagraj model provides a promising template for addressing non-recyclable plastic waste through co-processing, its widespread replication hinges on meticulous attention to regulatory frameworks, stakeholder collaboration, infrastructure suitability, waste characterization, financial sustainability, public awareness, local customization, and effective monitoring mechanisms. Successful adaptation of these elements can pave the way for a mutually beneficial and sustainable solution to the plastic waste challenge in other Indian cities.

5. Way forward and recommendations

Increasing the capacity of co-processing plants and promoting the usage of non-recyclable plastics as a replacement of virgin fuel: India has a substantial journey ahead in promoting the thermal substitution of fossil fuels with alternative fuels and raw materials (AFRs), including segregated combustible fraction (SCF), refuse-derived fuel (RDF) and biomass. In comparison to the global average, where approximately 19 per cent of fossil fuel has been replaced by AFR, the European Union stands out with a thermal substitution rate (TSR) of about 40 per cent, with 26 per cent attributed to waste and an additional 14 per cent from biomass.

Certain countries, such as the Netherlands, Austria, and Germany, have made significant impacts by co-processing RDF in cement plants, achieving an impressive range of replacing 60–70 per cent of their total coal consumption. On the contrary, India currently lags behind with average TSR in the cement industry estimated at a mere 4 per cent. It is interesting to note that the share of RDF in this substitution rate is less than 1 per cent.[12]

To bridge this gap and align with global best practices, cement co-processing industries must intensify their efforts to enhance the utilization of AFR, especially RDF, in the cement industry. Promoting the usage of plastic waste or any other combustible materials derived from legacy waste biomining or from fresh municipal solid waste would need a strong policy intervention in the law.

Policy interventions: The usage of SCF/RDF from legacy waste dumpsites or fresh MSW needs policy intervention in the form of amendment of the Solid Waste Management Rules, 2016. In the guidelines issued by the Central Public Health and Environmental Engineering Organisation (CPHEEO), Ministry of Housing and Urban Affairs (MoHUA) in 2016, one of the recommendations was that the

> Currently under the "Duties of the industrial units located within one hundred km from the refused derived fuel and waste to energy plants based on solid waste" mentioned under the Solid Waste Management Rules, 2016: All industrial units using fuel and located within one hundred km from a solid waste based RDF plant shall make arrangements within six months from the date of notification of these rules to replace at least five per cent of their fuel requirement by RDF.

cement plants located within 400 km of a solid waste-based RDF plant shall make necessary arrangements to utilize RDF in the following phase-wise manner at a price fixed by the state government:

- **Phase 1:** Replace at least 6 per cent of fuel intake within one year from the date of amendment of these rules (equivalent calorific value/thermal substitution rate) by MSW-based SCF and/or RDF, subject to the availability of RDF.
- **Phase 2**: Replace at least 10 per cent of fuel intake within two years from the date of amendment of these rules (equivalent calorific value/thermal substitution rate) by MSW-based SCF and/or RDF, subject to the availability of RDF.
- **Phase 3**: Replace at least 15 per cent of fuel intake within three years from the date of amendment of these rules (equivalent calorific value/thermal substitution rate) by MSW-based SCF and/or RDF, subject to the availability of RDF.

The transport cost for SCF/RDF up to 100 km from the cement plant shall be borne by the cement plant; however, beyond 100 km, the cement plant can transport at its own cost or the cost can be borne by ULBs as mutually agreed upon by the parties.

However, no amendment addressing these issues has been made so far in the Solid Waste Management Rules, 2016.

Developing standards for good quality SCF and RDF: Standardization guidelines are essential to encourage the widespread adoption of SCF and RDF in cement co-processing plants and other thermal treatment applications. One crucial aspect of standardization is ensuring the quality of feedstock (combustible materials from legacy waste dumpsites and fresh MSW), which plays a pivotal role in the efficient and sustainable utilization of these alternative fuels. However, it is noteworthy that existing guidelines lack specific quality assessment standards for feedstock.

The standards should encompass various parameters related to the composition, calorific value, moisture content, and other relevant characteristics of the feedstock. The establishment of such standards will not only ensure the consistency and reliability of the input materials but also contribute to the overall efficiency and environmental performance of cement co-processing plants.

Achieving standardization requires collaborative efforts from key stakeholders, particularly cement manufacturers, research and development institutions and regulatory bodies. Cement manufacturers should take the lead in initiating collaborative measures for research and development focused on establishing quality standards for SCF and RDF. The involvement of organizations such as the National Council for Cement and Building Materials (NCBM) and the Department of Industrial Policy & Promotion (DIPP) is crucial in providing a regulatory framework and support for the development and implementation of these standards.

Promoting and adopting tripartite agreement between urban local bodies, third party contractors engaged in biomining operations and cement plants: The operational strategy applied in Prayagraj for disposal of combustible materials recovered from legacy waste dumpsites, by using EPR liability and the utilization of cement kilns, has the potential to be replicated in various other cities across India. This is one model which has created a win-win situation for all the stakeholders involved including the urban local body, the cement industry and the third party contractor engaged in biomining operations.

Onsite treatment and other funding mechanisms: To ensure scientific disposal of SCF recovered from biomining of legacy waste dumpsites, ULBs shall manage necessary investments for onsite treatment (through gasification or pyrolysis or torrification) either by themselves or through a private company selected through a competitive bidding process on agreed terms and conditions. The Swachh Bharat Mission (SBM) funds may also be utilized in setting up such plants.

R&D on treatment options: Research and Development (R&D) endeavours should be promoted to explore novel methods of transforming RDF into liquid, solid or gaseous fuels, as well as other innovative alternatives. The goal should be to develop efficient and economically feasible processes that hold the potential for replication on a broader scale. If proven successful, this initiative has the capability to diversify RDF applications, presenting innovative pathways for its effective utilization.

Likewise, R&D initiatives should also be undertaken by other energy intensive industries (such as steel industry, thermal power plants, etc.) in order to make appropriate design changes in their infrastructure which can promote usage of SCF/RDF as a replacement of virgin fuel in consultation with relevant stakeholders. Investment on dealing with gaseous emissions from combustibles, particularly plastics, should be of prime importance.

Promoting end-to-end disposal and efficient biomining operations in cities: In many Indian cities, biomining process often begins by engaging a third-party concessionaire, but it typically remains confined to bioremediation and sorting of legacy waste fractions. Unfortunately, once the waste is sorted, the contractors are not held accountable for its final disposal. This results in the accumulation of RDF and SCF in city premises for extended periods, prompting the city to struggle in procuring subsequent tenders for the disposal of the recovered SCF/RDF.

To overcome such challenges, it is advisable to establish end-to-end contracts for biomining, encompassing bioremediation, treatment, and the scientific disposal of SCF and fine-soil materials in an appropriate manner. Additionally, it is essential to ensure that legacy waste undergoes treatment following all specified steps. Observations reveal that judiciously conducted biomining operations are crucial, as poor execution can lead to the production of low-quality SCF, rendering it unsuitable for cement co-processing plants. Therefore, a holistic approach to biomining contracts, encompassing the entire process and emphasizing the treatment and disposal aspects, is essential for effective and sustainable waste management in urban areas.

Phasing out disposal of combustible waste in landfills/dumpsites: As mandated by the Solid Waste Management Rules, 2016, combustible materials, including plastics, should not end up in landfills. It has been consistently observed, including in the present study, that recyclable plastics, especially high-value plastics, are not typically found in Indian landfills due to the intervention of the informal sector. However, a substantial quantity of plastics in dumpsites or landfills comprises primarily single-use plastics, such as carry bags and multi-layered packaging materials.

To address this issue and align with the long-term vision of the Swachh Bharat Mission (SBM) 2.0, which emphasizes the phase-out of single-use plastics, it is crucial to ensure that future waste sites do not accumulate plastics and other combustibles. The management of recovered materials becomes exceedingly challenging in terms of cost and available infrastructure when dealing with combustible materials containing plastics. Therefore, proactive measures are essential to prevent the creation of future waste sites that aggravate the difficulties associated with SCF management.

Annexures

ANNEXURE I: List of waste-to-energy plants in India

Sr. no.	State	Name	Address	Email	Category	CAT I	CAT II	CAT III	CAT IV	Total Processing Capacity
1	Andhra Pradesh	M/s. Jindal Urban Waste Management Guntur Limited	Sy. No. 933 & 938, Kondaveedu (V) Edlapadu (M), Palnadu District, A.P	seelam.chandrayudu@jindalecopolis.com	CAT II		40,918			40,918
2	Andhra Pradesh	Jindal Urban Waste Management Visakhapatnam Limited	Sy.No. 410 & 415, Kapuluppada Village, GVMC Dumping Yard, Bheemunipatnam Mandal, Visakhapatnam District, Andhra Pradesh	Sathish.V@jindalecopolis.com	CAT II		40,918			40,918
3	Delhi	Timarpur-Okhla Waste Management Company Limited	Old NDMC Compost Plant, Behind CRRI Mathura Road Okhla, Delhi 110025	sandip.dutt@jindalecopolis.com	CAT I, CAT II, CAT III	39,542	47,4500	197,708		711,750
4	Delhi	Delhi MSW Solutions Limited	Sector 5, Pocket N-1, Bawana Industrial Area, Bawana, New Delhi, Delhi	laboratorynarela@resustainability.com	CAT I, CAT II, CAT III	10,950	62,050	109,500		182,500
5	Delhi	Tehkhand Waste to Electricity Project Limited	Adjacent DTC Tehkhand Depot, Maa Anandmai Marg, Tehkhand, New Delhi-110020	info.twepl@jindalecopolis.com	CAT I, CAT II, CAT III	40,556	486,667	202,778		730,001
6	Delhi	East Delhi Waste Processing Company Private Limited	Adjacent to Veterinary Hospital, Behind Ghazipur DDA Flats, Ghazipur, Delhi-110096	kiran.tiwari@everenviro.com	CAT II, CAT III		33,215	144,905		178,120
7	Gujarat	Goodwatts WtE Jamnagar Private Limited	Plot no. 46/1, 46/2/P-1, 47, 48, 49/1, 49/2, 50/1, 50/2, 53, Navagam (Ghed)	eprservices@abellon.com	CAT I, CAT II, CAT III	4,130	8,260	28,910		41,300
8	Gujarat	Mehali Papers Private Limited	Mehali Papers Pvt. Ltd., Plot No. D-2/11/B/2, GIDC, Dahej– 392130. Tal-Vagra, Dist.-Bharuch.	ashraf@mehali.com	CAT II		9,600			9,600
9	Gujarat	Shah Paper Mills Ltd.	Plot No. 5202, Phase-III, GIDC Estate, Vapi – 396195, Dist. Valsad.	gsshetty@shahpaper.com	CAT II		7,300			7,300
10	Gujarat	Best Paper Mills Pvt. Ltd. (Unit-II)	Plot No. 57, FGH/B2, Phase – I, GIDC Estate, Vapi– 396195, Dist. Valsad.	bijoy@bestpaper.co.in	CAT II		5,256			5,256
11	Gujarat	Gayatrishakti Paper & Boards Ltd	PLOT NO. 5003 & 5003/1, PLASTIC ZONE, MANDA COLONY, GIDC, SARIGAM-396155	vijay.patil@gspbl.com	CAT II		10,500			10,500

Sr. no.	State	Name	Address	Email	Category	CAT I	CAT II	CAT III	CAT IV	Total Processing Capacity
12	Gujarat	N R Agarwal Industries Limited	PLOT NO. 169, IInd PHASE, GIDC, VAPI	vijay.patil@nrail.com	CAT II		2,700			2,700
13	Haryana	M/s JBM Environment Management Private Limited	Near 132 KV HVPNL Tajpur Substation, Tajpur-Murthal Road, Murthal Village, Sonipat, Haryana - 131027	jbmempl.ehs@jbmgroup.com	CAT I, CAT II, CAT III, CAT IV		38,325	43,800	0	82,125
14	Himachal Pradesh	Elephant Energy Pvt.Ltd.	ISHAN BHAWAN DIVYA NAGAR AIRPORT ROAD SHIMLA	manojdepta@elephantenergy.in	CAT II, CAT III		6,500	10,000		16,500
15	Himachal Pradesh	Kumar Yogesh Chandra	Test	yogesh17@gmail.com	CAT I, CAT III	1,000		1,000		2,000
16	Karnataka	M/s 3F Industries Limited	NA	test1006@kl.com	CAT II		10,000			10,000
17	Madhya Pradesh	Jabalpur MSW Pvt. Ltd	Khasra No 375 376379 Village Kathonda,Patwarihalka No 23 R.I Circle Maharajpur Tehsil Jabalpur 482004 Madhya Pradesh	Narendra.Sahare@utility.esselgroup.com	CAT II, CAT III		55,000	16,1000		216,000
18	Tamil Nadu	Hva chemical solution private limited	3/845C1, Murugan Kovil street, Bharathi Nagar west, paramakudi.	anbarasanhv@gmail.com	CAT III			300		300
19	Telangana	Hyderabad MSW Energy Solutions Private Limited	Survey No.173, CRPF Road, Jawahar Nagar Dump Site, Kapra	bhaskar.boge@resustainability.com	CAT I, CAT II, CAT III	100,740	240,900	96,360		438,000
20	Uttar Pradesh	Accord Hydroair (Swm) Barabanki Pvt Ltd	Village-banwa,faizullahganj,near palhari tampo stand barabanki	Swm@marsgroup.org	CAT I, CAT II, CAT III	2,000	4,000	21,375		27,375
21	Uttar Pradesh	Rollz India Waste Management Pvt Ltd	293M, Village Deenanathpur Puthi, Dasna, Ghaziabad - 201015	ankit@rollzindia.com	CAT II, CAT III		16,200	10,800		27,000
22	Uttar Pradesh	K K Duplex and Paper Mills Private Limited	8.5 km Jansath Road	bharat@kkduplex.com	CAT III			36,000		36,000
23	Uttar Pradesh	Silvertoan Papers Limited	9 KM, Bhopa Road, Makhyali, Muzaffarnagar, Uttar Pradesh, 251002	silvertoanpapers@rediffmail.com	CAT II, CAT III		32,500	77,000		109,500
24	Uttar Pradesh	M/S Suchi Paper Mills Limited	589/2 Bisrakh Road Industrial Area, Chapraula, Gautam Budh Nagar - 201009	NA	CAT 1, CAT II, CAT III	5,475	38,325	5,475		49,275

Sr. no.	State	Name	Address	Email	Category	CAT I	CAT II	CAT III	CAT IV	Total Processing Capacity
25	Uttar Pradesh	M/S Crystal Bajaj Industries Private	Khasra No. 921M, 921/1001, Begraipur, Tehsil-Khatauli, Muzaffarnagar - 251203	NA	CAT II, CAT III		52,470	122,430		174,900
26	Uttar Pradesh	M/S Ankita Papers Limited	C-10 Industrial Estate, Panipat Road, Shamli - 247776	NA	CAT II, CAT III, CAT IV		31,440	57,640	15,720	104,800
27	Uttar Pradesh	Silverton Pulp and Papers Private Limited	09th KM Bhopa Road, Muzaffarnagar - 251001	NA	CAT I, CAT II. CAT III, CAT IV	16,425	123,187.5	21,352.5	3,285	164,250
28	Uttar Pradesh	Siddheshwari Industries Private Limited	8.6 KM, Jansath Road, Muzaffarnagar - 251001		CAT I, CAT II. CAT III, CAT IV	4,380	32,850	5,694	876	43,800
29	Uttar Pradesh	Shree Bhageshwari Papers Private Limited	09th KM Bhopa Road, Muzaffarnagar - 251001		CAT I, CAT II. CAT III, CAT IV	8,030	60,225	10,439	1,606	80,300
30	Uttarakhand	Bahl Paper Mills Limited	5 KM. Stone, Aliganj Road,Kashipur	bahlpapergst@gmail.com	CAT I, CAT II, CAT III, CAT IV	1,500	10,000	20,000	1500	33,000

Source: Compiled from the CPCB's EPR portal as on 20 August 2024

ANNEXURE 2: List of cement co-processing plants in India

Sr. no.	State	Name	Address	Email	Category	CAT I	CAT II	CAT III	CAT IV	Total processing capacity
1	Andhra Pradesh	JSW Cement Limited	M/S JSW Cement Limited, Bilakalaguduru (V), Gadivemula (M), Nandyal - 518501	ceo.cement@jsw.in	CAT I, CAT II, CAT III, CAT IV	10,000	80,000	10,000	5,600	105,600
2	Andhra Pradesh	Dalmia Cement Bharat Limited	Chinnakomerla Village, Mylavram Mandal, Ysr District	m.pullaiahvenkata@dalmiacement.com	CAT I, CAT II, CAT III	4,000	45,000	50,000		99,000
3	Andhra Pradesh	M/s. Chettinad Cement Corporation Private Limited	Pedagarlapadu (V) & Kesanupalli (V), Dachepalli (M), Guntur – 522437	environdachepalli@chettinadcement.com	CAT I, CAT II, CAT III	10,000	25,000	14,000		49,000
4	Andhra Pradesh	Sagar Cements R Limited	Plot No: 111, Road No:10, Jubilee Hills, Hyderabad - 500033	environment-r@sagarcements.in	CAT II, CAT III		100	200		300
5	Andhra Pradesh	Zuari Cement Ltd	Krishnagar, Yerraguntla, Kadapa, Kadapa, Andhra Pradesh - 516311	v.madhavareddy@zcltd.com	CAT II, CAT III		35,000	35,000		70,000
6	Andhra Pradesh	Parasakti Cement Industries Limited	Swarna Residency, 0-1, Near Govt. PF office, 4th Lane, Krishna nagar, Guntur - 522006	mrr@parasakticement.com	CAT I, CAT II, CAT III, CAT IV	450	450	200	200	1,300
7	Assam	Calcom Cement India Limited	3rd And 4th Floor Anil Plaza II ABC G S Road Guwahati	kumar.subodh@dalmiacement.com	CAT I, CAT III	1,22,000		10,000		1,32,000

Sr. no.	State	Name	Address	Email	Category	CAT I	CAT II	CAT III	CAT IV	Total processing capacity
8	Bihar	Dalmia Cement (Bharat) Limited	Trichy-Chidambaram Salai, Dalmiapuram, Tiruchirapalli - 621651	sandwar.binay@dalmiacement.com	CAT I, CAT II, CAT III	5,250	50,000	70,000		1,25,250
9	Chhattisgarh	UltraTech Cement Ltd	Rawan, Grasim Vihar, Balodabazar-Bhatapara - 493196	***	CAT I, CAT II, CAT III, CAT IV	1,722	87,378	84,378	1,722	1,75,200
10	Chhattisgarh	UltraTech Cement Limited	Hirmi, Simga, Balodabazar-Bhatapara - 493195	hcw-utcl.env@adityabirla.com	CAT I,CAT II,CAT III,CAT IV	56,205	51,205	1,045	1,045	1,09,500
11	Chhattisgarh	Shree Raipur Cement Plant	Bharuadih-Semradih, Balodabazar, Baloda Bazar -Bhatapara Chhattisgarh-493332	srcpenvironment@shreecement.com	CAT I,CAT II,CAT III,CAT IV		1,20,000	4,80,000		6,00,000
12	Chhattisgarh	JK Lakshmi Cement Limited	Kodiya, Bhilai, Chhattisgarh 490036	envdurg@durg.jkmail.com	CAT II		10,000			10,000
13	Chhattisgarh	Ambuja Cements Limited Bhatapara	Bhatapara Cement Works Rawan Baloda Bazar Raipur Chhattisgarh	samrat.sarkar@adani.com	CAT I,CAT II,CAT III,CAT IV	99,000	99,000	22,000	6,000	2,26,000
14	Delhi	CPCB_TEST_3	Parivesh Bhawan	cpcbyogesh@gmail.com	CAT I,CAT II	1,000	1,000			2,000
15	Gujarat	Ambuja Cements Limited Rabriyawas	Po Ambuja Nagar Kodinar Gir Somnath	dileepkumar.katiyar@adani.com	CAT I,CAT II,CAT III,CAT IV	75,000	69,000	5,000	1,000	1,50,000
16	Gujarat	Gujarat Cement Works (A unit of UltraTech Cement Limited)	Village-Kovaya, Taluka-Rajula	gcwkovaya.cpcb@adityabirla.com	CAT I,CAT II,CAT III,CAT IV	2,62,800	2,62,800	2,62,800	2,62,800	10,51,200
17	Gujarat	UltraTech Cement Limited (Unit-Narmada Cement Jafarabad Works)	Village- Babarkot, Taluka-Jafarabad, District- Amreli	ncjw.cpcb@adityabirla.com	CAT I,CAT II,CAT III,CAT IV	87,600	87,600	87,600	87,600	3,50,400
18	Gujarat	Tata Chemicals Limited	Bombay House 24 Homi Mody Street Fort Mumbai 400 001	sanjeev.jain@tatachemicals.com	CAT I,CAT II,CAT III	3,650	3,650	3,650		10,950
19	Himachal Pradesh	UltraTech Cement Ltd. (Unit Baga Cement Works)	53a/15/Sw (City Survey); 511 (Had Bast No.)	***	CAT I,CAT II,CAT III,CAT IV	980	29,010	23,520	490	54,000
20	Himachal Pradesh	Deepak Jasuja	Ambuja Cements Ltd. Darlaghat,	hemraj.sharma9@adani.com	CAT I,CAT II,CAT III,CAT IV	20,000	20,000	20,000	20,000	80,000

Sr. no.	State	Name	Address	Email	Category	CAT I	CAT II	CAT III	CAT IV	Total processing capacity
21	Himachal Pradesh	ACC Limited Gagal	ACC Limited Gagal Cement Works Po Barmana Bilaspur Himachal Pradesh	sandeep.sharma@acclimited.com	CAT II,CAT III		5,000	2,200		7,200
22	Himachal Pradesh	M/s 3F Industries Limited	Himachal Pradesh	copro@test.com	CAT I,CAT II,CAT III	10,000	10,000	10,000		30,000
23	Karnataka	JK Cement works, Muddapur (Unit: JK Cement Ltd),	Kamla Tower, Kanpur, 208001, U.P, India	Umashankar.Choudhary@jkcement.com	CAT I,CAT II,CAT III,CAT IV	25,000	1,00,000	25,000	8,400	1,58,400
24	Karnataka	Orient Cement Limited	Unit Viii Plot No 7 Bhoinagar Bhubaneshwar Odisha 75012	satyabrata.sharma@orientcement.com	CAT I,CAT II,CAT IV	600			600	1,200
25	Madhya Pradesh	UltraTech Cement Limited, Unit – Vikram Cement Works	Vikram Nagar, P.O. Khor, Tehsil - Jawad, District – Neemuch (M.P.) Pin Code 458470	utcl-vcw.cpcb@adityabirla.com	CAT I,CAT II,CAT III,CAT IV	87,600	87,600	87,600	87,600	3,50,400
26	Madhya Pradesh	UltraTech Cement Limited, (Unit-Maihar Cement Works)	P.O. Sarlanagar, Maihar, Tahsil- Maihar, Distt. Satna-485772 (M.P.)	mcw.env@adityabirla.com	CAT II		5,000			5,000
27	Madhya Pradesh	M/s. Sagar Cements (M) Private Limited	602/A And 602/B, Airen Heights, Pu-3, Scheme No.54, Opp. C-21 Mall, A.B. Road, Indore Mp 452001 In	scmpl.env@sagarcements.in	CAT II		840			840
28	Madhya Pradesh	ACC Limited Kymore	Acc Limited Kymore Cement Works	gaurav.kushwaha@adani.com	CAT I,CAT II,CAT III,CAT IV	42,000	26,000	5,000	2,000	75,000
29	Madhya Pradesh	KJS Cement (I) Limited	Nh-7, Rewa Road, Rajnagar, Maihar, Amilia-Lakhwar, Satna, Madhya Pradesh, 485771	devendra.singh@kjscement.com	CAT II		2,520			2,520
30	Madhya Pradesh	Prism Johnson Limited (Cement Division)	Prism Johnson Limited, Village Mankahari, P.O,- Bathia, Dist. Satna - 485111 (M.P.)	manoj.kumar@prismjohnson.in	CAT II		40,000			40,000
31	Madhya Pradesh	Heidelberg Cement India Limited	Heidelberg Cement India Ltd., Narsingarh Damoh, Madhya Pradesh,470675	env.narsingarh@mycem.in	CAT I,CAT II,CAT III,CAT IV	5,000	35,000	5,000	5,000	50,000
32	Madhya Pradesh	Birla Corporation Limited, Unit-Satna Cement Works	P.O : Birla Vikas, Satna Cement Works, Satna (M.P.) - 485005	ankit.gautam@birlacorp.com	CAT I,CAT II,CAT III,CAT IV	1,000	15,000	3,000		19,000
33	Madhya Pradesh	Prism Johnson Limited (Cement Division) - Unit-II	Prism Johnson Limited, Village Mankahari, P.O,- Bathia, Dist. Satna - 485111 (M.P.)	pwp.unit2@prismjohnson.in	CAT II		60,000			60,000

Sr. no.	State	Name	Address	Email	Category	CAT I	CAT II	CAT III	CAT IV	Total processing capacity
34	Madhya Pradesh	Jaypee Rewa Plant	Jaypee Nagar Rewa (M.P.)	jrp.envcell@jalindia.co.in	CAT IV				8,140	8,140
35	Madhya Pradesh	M/S Bhilai Jaypee Cement Limited	Village Post - Babupur ,Tehsil-Raghuraj Nagar, Dist -Satna , Mp-485112	bjclbabupur.environment@jalindia.co.in	CAT IV				150	150
36	Maharashtra	Ultratech Cement Limited Unit – Manikgarh Cement Works I & II	At Post- Gadchandur Tah-Korpana Dist- Chandrpaur	mcw.cpcb@adityabirla.com	CAT I,CAT II,CAT III,CAT IV	1,500	15,000	12,000	1,500	30,000
37	Maharashtra	Murli Industries Limited, Subsidiary of Dalmia Cement (Bharat) limited	Murli Industries Limited, Village Naranda,, Tq Korpana, District Chandrapur, Maharashtra	banwade.nikesh@dalmiacement.com	CAT I,CAT III	9,000		81,000		90,000
38	Maharashtra	Ambuja Cements Limited Maratha	Ambuja Cements Limited Maratha Cement Works Upparwahi Korpana Chandrapur	sayam.chatterjee@adani.com	CAT I,CAT II,CAT III,CAT IV	95,000	85,000	10,000	5,000	1,95,000
39	Maharashtra	Dalmia Cement Bharat Limited	Unit Chandrapur Cement Works, Village Naranda, Tehsil Korpana, District Chandrapur, Maharashtra	dcbl.ccwenv@dalmiacement.com	CAT I,CAT II,CAT III	9,900	79,200	1,08,900		1,98,000
40	Meghalaya	M/s. Dalmia Cement Bharat Limited	Umsoo Mootang,Thangskai	nath.shibasish@dalmiacement.com	CAT I,CAT III	16,500		1,65,000		1,81,500
41	Meghalaya	M/s Meghalaya Cements Limited	Vill-Thangskai, Po-Lumshnong, Dist-East Jaintia Hills, Meghalaya, Pin-793210	***	CAT II		10,000			10,000
42	Odisha	Dalmia Cement (Bharat) Limited, Rajgangpur	Rajgangpur, Distt - Sundargarh,Odisha-770017	mishra.ashok2@dalmiacement.com	CAT I,CAT II,CAT III	9,075	72,600	99,825		1,81,500
43	Odisha	Dalmia Cement (Bharat) Limited	Rajgangpur, Distt - Sundargarh,Odisha-770017	patra.bhabagrahi@dalmiacement.com	CAT I,CAT II,CAT III	11,000	88,000	1,21,000		2,20,000
44	Rajasthan	J K Cement Works Nimbahera, Tehsil Nimbahera	J K Cement Ltd, Kamla Tower Kanpur (Up) 208001	nilesh.sharma@jkcement.com	CAT I,CAT II,CAT III,CAT IV	15,000	7,50,000	10,000	10,000	7,85,000
45	Rajasthan	J K Cement Works Mangrol, Tehsil Nimbahera, Dist Chittorgarh, Rajasthan	J K Cement Ltd, Kamla Tower Kanpur (Up) 208001	sunil.singh@jkcement.com	CAT I,CAT II,CAT III,CAT IV	15,000	75,000	10,000	10,000	1,10,000
46	Rajasthan	Wonder Cement Limited	Wonder Cement Limited, Corporate Office, 17 Old Fatehpura, Udaipur Rajasthan	amit.bharadwaj@wondercement.com	CAT I,CAT II,CAT III,CAT IV	5,000	45,000	40,000	10,000	1,00,000

Sr. no.	State	Name	Address	Email	Category	CAT I	CAT II	CAT III	CAT IV	Total processing capacity
47	Rajasthan	Udaipur Cement Works Limited	Shripati Nagar, Cfa, P.O. Dabok,	ajaysharma@ucwl.jkmail.com	CAT II		2,400			2,400
48	Rajasthan	Shree Cement Limited	Bangur Nagar, Post Box No. 33, Beawar 305901, Rajasthan, India	saurabh.agarwal3@shreecement.com	CAT II,CAT III		1,20,000	4,80,000		6,00,000
49	Rajasthan	Ultratech Cement Limited (Unit: Aditya Cement Works)	Po Adityapuram, Chittorgarh-312622	utcl-ac.cpcb@adityabirla.com	CAT I,CAT II,CAT III,CAT IV	10,000	2,50,000	46,800	10,000	3,16,800
50	Rajasthan	Mangalam Cement Ltd.	P. O. Aditya Nagar Morak, Distt Kota (Rajasthan) Pin - 326520	safety@mangalamcement.com	CAT II		12,000 12,000			24,000
51	Rajasthan	Shree Cement Limited	Shree Cement Limited, Bangur Nagar, Post Box No.-33, Beawar 305901, Rajasthan	girdhari.yadav@shreecement.com	CAT I,CAT II,CAT III,CAT IV	-	2,42,400	9,69,600		12,12,000
52	Rajasthan	UltraTech Nathdwara Cement Ltd. (Unit : Nathdwara Cement Works)	Unit: Nathdwara Cement Works Tehsil : Pindwara, P.O. : Adityanagar District : Sirohi (Rajasthan)	Utcl-ndcw.env@adityabirla.com	CAT I,CAT II,CAT III,CAT IV	25,000	50,000	12,500	12,500	1,00,000
53	Rajasthan	M/s Nuvoco Vistas Corp. Ltd.	Equinox Business Park, Tower-3, East Wing, 4th Floor, Off Bandra- Kurla Complex Kurla, West Mumbai-40070	bharti.purohit@nuvoco.com	CAT I,CAT II,CAT III,CAT IV	22,000	22,000	22,000	22,000	88,000
54	Rajasthan	JK Lakshmi Cement Limited	Village- Jaykaypuram Tehsil:Pindwara District:Sirohi	jklcocemscement@lc.jkmail.com	CAT II		90,000			90,000
55	Rajasthan	The India Cements Limited	Near Vill. Vajwana,Tehsil Garhi,District Banswara,Rajasthan	bans_env@indiacements.co.in	CAT I,CAT II,CAT III,CAT IV	80	700	2,000	100	2,880
56	Tamil Nadu	Ultratech Cement Ltd	Reddipalayam Cement Works, Muttuvancherry Road, Reddipalayam Post, Ariyalur, Tamil Nadu, 621704	kumaravelu.m@adityabirla.com	CAT III			50,000		50,000
57	Tamil Nadu	Dalmia Cement (Bharat) Limited	Dalmia Cement (Bharat) Limited, Dalmiapuram, Tiruchirappalli, Tamil Nadu - 621651	br.prasannakumar@dalmiacement.com	CAT I,CAT II,CAT III	18,150	54,450	1,08,900		1,81,500
58	Tamil Nadu	Dalmia Cement (Bharat) Limited	Dalmiapuram, Lalgudi-Tk, Trichy-Dist	r.rajamohan@dalmiacement.com	CAT I,CAT II,CAT III	18,150	54,450	1,08,900		1,81,500
59	Tamil Nadu	Chettinad Cement Corporation Private Limited, Karikkali Works	Chettinad Cement Corporation Private Limited, Rani Meyyammai Nagar, Karikkali Village, Guziliamparai Taluk, Dindigul District, Tamilnadu - 624703	senthilvel.av@chettinadcement.com	CAT II,CAT III		20,000	20,000		40,000

Sr. no.	State	Name	Address	Email	Category	CAT I	CAT II	CAT III	CAT IV	Total processing capacity
60	Tamil Nadu	Chettinad Cement Corporation Private Limited	Rani Seethai Building, 603, Anna Salai,	ramesh.v@chettinadcement.com	CAT II,CAT III		20,000	20,000		40,000
61	Tamil Nadu	M/s Chettind cement Corporation Private Limited,Karur	Chettinad Towers, 4th Floor, 603 Annasalai,Chennai-600006	puliyur@chettinadcement.com	CAT II,CAT III		20,000	20,000		40,000
62	Tamil Nadu	Dhandapani Cements Private Ltd.,	94, Kariyamanickam Road, S.Pudhur, Samayapuram (P), Mannachanallur (Tk),Trichy	dcplmaruthi@gmail.com	CAT II		1,200			1,200
63	Tamil Nadu	The India Cements Limited	Dhun Building, 827, Anna Salai, Chennai - 600 002.	veerabagu.a@indiacements.co.in	CAT II,CAT III		2,500	800		3,300
64	Tamil Nadu	The Ramco Cements Limited	Ramamandiram, Rajapalayam	bobbypravin@ramcocements.co.in	CAT II,CAT III		1,58,400	1,58,400		3,16,800
65	Tamil Nadu	The Ramco Cements Limited - Alathiyur Works	Ramamandiram, Rajapalayam	baskars@ramcocements.co.in	CAT II,CAT III		13,000	7,700		20,700
66	Tamil Nadu	The Ramco Cements Limited	Ramamandiram, Rajapalayam	srmn@ramcocements.co.in	CAT I,CAT II,CAT III	1,500	1,500	1,500		4,500
67	Tamil Nadu	M/S The India Cements Limited	M/S The India Cements Ltd, Dalavoi Works, Sendurai Taluk, Ariyalur District, Cement Nagar Post - 621730	***	CAT II		6,250			6,250
68	Tamil Nadu	M/S The India Cements Limited	No. 17, Madurai Road, Sankarnagar	***	CAT I,CAT II,CAT III	500	3,000	1,000		4,500
69	Tamil Nadu	M/S Tamil Nadu Cements Corporation Limited	Ariyalur Cement Factory, Ariyalur - 621729	***	CAT I,CAT II,CAT III,CAT IV	3,960	3,960	3,960	3,960	15,840
70	Telangana	My Home Industries Private Limited	9th Floor, Block-3, My Home Hub, Madhapur, Hyderabad-500081.	mcwenv@myhomeindustries.in	CAT I,CAT II,CAT III	100	4,200	320		4,620
71	Telangana	Orient Cement Limited	Devapur Village, Kasipet Mandal, Mancherial District, Telangana - 504218	orcem.env@orientcement.com	CAT I,CAT II,CAT III	1,200	19,200	3,600		24,000
72	Telangana	NCL Industries Limited	Shimhapuri (PO), Mattapally (V),Mattampally(M), Suryapet District – 508204. Telangana Suryapet 508204	sitaram@nclind.com	CAT I,CAT II,CAT III	50	3,700	250		4,000
73	Telangana	Sagar Cements Limited	Plot No.111, Road No.10, Jubilee Hills, Hyderabad	envmtpl@sagarcements.in	CAT I,CAT II,CAT III	100	4,300	500		4,900

Sr. no.	State	Name	Address	Email	Category	CAT I	CAT II	CAT III	CAT IV	Total processing capacity
74	Telangana	M/S Zuari Cement Limited	Village- Dondapadu, Mandal- Chintalapalem,	m.gopalakrishna@zcltd.com	CAT I,CAT II,CAT III,CAT IV	100	3,000	200	100	3,400
75	Telangana	Kesoram Cement Factory, Cement Division unit of Kesoram Industries Ltd.	Basantnagar(Post)	s.sateesh@kesoram.com	CAT I,CAT II,CAT III	500	3,000	500		4,000
76	Telangana	Deccan Cements Limited	Bhavanipuram, Janpahad, Palakeedu	pqc@deccancements.com	CAT II		17,00,000			17,00,000
77	Telangana	The India Cements Limited	Vishnupuram, Wadapally (Post), Dama	prasad.b@indiacements.co.in	CAT I,CAT II,CAT III,CAT IV	300	1,000	400	100	1,800
78	Telangana	Anjani Portland Cement Limited	4th Floor Queena Square, Taj Deccan Road, Erramanzil, Hyderabad 500082	dssarjun@gmail.com	CAT IV				100	100
79	Telangana	The India Cements Ltd	Malkapur Village, Tandur Mandal, Vikarabad Dist, Telangana-501158	mkp_gmoffice@indiacements.co.in	CAT I,CAT II,CAT III	100	50	40		190
80	Uttar Pradesh	UltraTech Cement Limited unit Dalla Cement Works	Sh-5,Post: Dalla, Distt. Sonebhadra(UP)	***	CAT I,CAT II,CAT III,CAT IV	60,000	60,000	60,000	60,000	2,40,000

Source: Compiled from the CPCB's EPR portal as on 20 August 2024

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This report explores the potential and challenges associated with the segregated combustible fraction (SCF) recovered from legacy waste dumpsites in India. These materials are typically contaminated with inert substances and exhibit high moisture content, complicating their scientific disposal. A significant challenge is the high transportation costs associated with transporting these segregated combustible fractions to cement co-processing units or waste-to-energy plants. This report delves into strategies for optimizing the utilization of these fractions, addressing logistical hurdles, and advancing sustainable legacy waste management practices in India.

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