India's current and potential MSW use in RDF production

Annual municipal solid waste (MSW) generation in India is estimated to be 62Mt (urban) to >275Mt (pan India), which is projected to increase with the country's growing population, urbanisation and changing consumption patterns. To achieve a thermal substitution rate (TSR) of 25 per cent by 2025 in the Indian cement industry, more than 50 per cent of the alternative fuel (AF) mix will be refuse-derived fuel (RDF) produced from MSW.

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In 2013-14 urban India, with a population of 377m, generated 62Mta of municipal solid waste (MSW).[1] Other estimates pitch all-India numbers to be ranging from 110Mta[2] to 277Mta.[3] These estimates are indicative figures that need to be verified for national policy-making as well as for city-specific MSW management systems. Typically, MSW tends to be unsegregated, has a high moisture content and low calorific value, smells due to decomposition of organics and includes a wide range of particle sizes.

Due to changes in consumption patterns, the composition of MSW has changed over time to include more plastic and other packaging materials, such as multi-layered plastic. From its studies of 60 Indian cities in 2015, the country's Central Pollution Control Board (CPCB) has estimated that 9.4Mt (25,940tpd) of plastic waste were generated in 2017-18. The study found a plastic waste share of 3.1-12.5 per cent in the MSW.[4]

In India the non-recyclable plastic waste is generated through plastic use in food packaging, pharmaceuticals and cosmetic products, electrical and electronic goods and items used in food servings.[5] The country is estimated to release 0.09-0.24Mta of marine litter and ranks as the 12th-largest contributor of plastic waste to the ocean.[6] By 2031 plastic waste generation is expected to amount to 31Mta.[7]

"Due to changes in consumption patterns, the composition of MSW has changed over time to include more plastic and other packaging materials, such as multi-layered plastic."

India produced around 9.4Mt of plastic waste in 2017-18

In terms of disposal, a CPCB study in 2016[8] revealed that 90 per cent of MSW was collected and 25 per cent was processed or treated. The remaining quantities were mostly disposed of in open dumps.

About 60 per cent of plastic waste, or 5.6Mt, is recycled. Of this total, 70 per cent is recycled by registered facilities (3.9Mt), 20 per cent by the informal sector (1.1Mt) and 10 per cent (0.6Mt) at home.[9] An estimated 2.5Mta of plastic waste is dumped, more than 1Mta sent to incinerators and 0.25Mta is sent to large cement companies for co-processing.

India intends to eliminate all single-use plastic in the country by 2022 and several states have already banned single-use plastic. Co-processing in cement kilns has been given the highest priority for the management of non-recyclable plastic waste, followed by plasma pyrolysis and secured landfilling.[5]

Urban local bodies (ULBs) are responsible for collection, segregation and disposal of waste, and for ensuring a functioning waste management system in cities. However, due to the limited resources, institutional and governance gaps in the functioning of the ULBs, MSW management is an increasing challenge for the country. While choosing the treatment options, the waste management hierarchy should be respected for maximum material, energy recovery and to minimise landfilling/dumping.

Table 1: quality of RDF of different grades[5]

SN	Parameters	Segregated combustible fraction (SCF)	RDF Grade-III	RDF Grade-II	RDF Grade-I
1	Intended use	Input to WtE plant or pre-processing facility	Direct co-processing or for further processing	Direct co-processing	Direct co-processing
2	Size (mm)	>400 (or to be mutually discussed)	<50 (ILC) <20 (SLC)		
3	Maximum ash content (%)	<20%*	<15%	<10%	<10%
4	Maximum moisture content (%)	< 35%	< 20%	< 15%	< 10%
5	Maximum chlorine content (%)	< 1%*	< 1%	< 0.7%	< 0.5%
6	Maximum sulphur content (%)	< 1.5%*	< 1.5 %	< 1.5 %	< 1.5 %
7	Net calorific value – average of every consignment (kcal/kg) #	> 1500	> 3000	> 3750	> 4500
8	Odour	Offensive odour to be controlled			

** If sent to pre-processing facility, can be mutually agreed between ULBs, SCF supplier and cement plants.*
 # Bandwidth for net calorific value to be mutually agreed upon between RDF producer and cement plant.

Indian RDF guidelines (2018)

An expert committee, including members from ministries, ULBs, cement companies, bilateral organisations and academia drafted the RDF guidelines that were published by the Ministry of Housing and Urban Affairs (MoHUA) in 2018.[10] The RDF guidelines contain recommendations for promoting the use of MSW-based RDF for utilisation in various industries, with proposals on regulatory and fiscal incentives towards facilitating the objectives of the Swachh Bharat (Clean India) mission. Overall, the guidelines are considered an important step towards enhancing RDF utilisation, which is currently very low.

This expert committee has set the minimum criteria (eg, calorific value, ash, moisture, sulphur and chlorine) that should be met for the product to be certified as segregated combustible fraction (SCF) and for three grades of RDF (see Table 1).

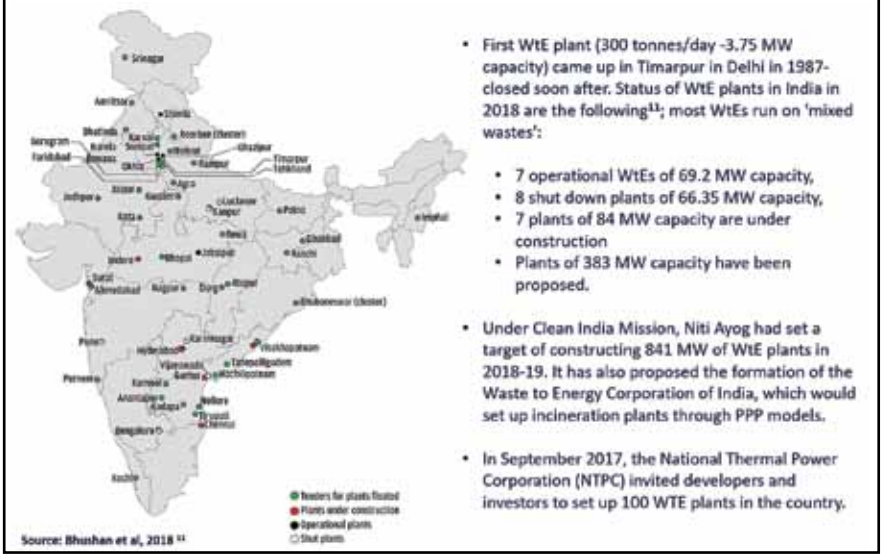
RDF utilisation in other energy-intensive industries

Utilisation of MSW-based RDF in thermal power plants is more challenging and has not progressed due to perceived technical limitations, although there is a trend of increasing interest and focus in this sector. The Indian steel industry currently has no or very limited experience in utilisation of MSW or RDF and is generally cautious about its implementation due to concerns over the possible negative impacts on the production process and product quality.

The waste-to-energy (WtE) option is an increasingly-popular choice for Indian cities due to the rising waste quantities and limited success in the adoption of co-processing (see Figure 1). WtE normally involves the generation of electricity in steam turbines in either mass burn mode or by first producing RDF. In either case, the efficiency of the process is low and achieving continuous operation like a thermal power plant has not been possible. Further, such plants are expensive to build and operate. They also represent an additional emission source and produce large amounts of residues (fly ash, bottom ash, etc) that still need to be landfilled. Another challenge is the incineration of wet wastes in the rainy season, which causes difficult burning conditions and results in further emissions.

In Europe WtE is considered a reliable method of treatment of waste for which there is no other alternative towards a circular economy. The success of WtE in Europe can be attributed to the regulatory framework against landfilling, which also favours waste utilisation in the cement industry.

Figure 1: status of waste-to-energy plants in India, 2018



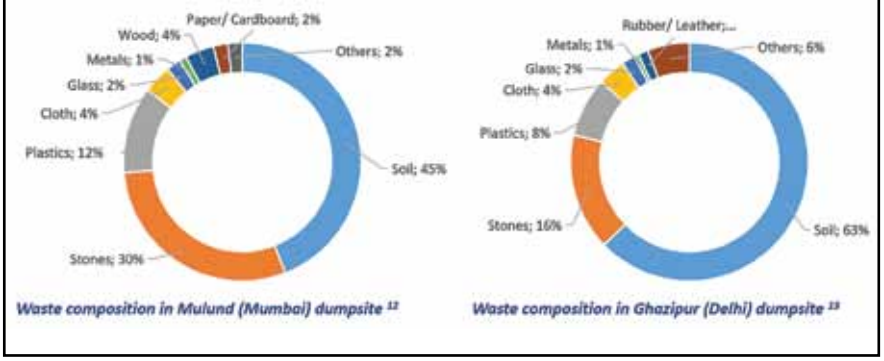
RDF availability for the cement industry

Currently, MSW generation in a 200km radius of a cement plant in India is around

143,379tpd and therefore, considering a 20 per cent yield, approximately 28,676tpd of RDF will be available for co-processing in the cement plants. With the assumption that part of the segregated combustible fraction will be used in WtE, 13,600tpd (~5Mta) of RDF will be finally available for co-processing.[10]

According to the data gathered by CII-GBC, there are 25 RDF production facilities in India. This is not an exhaustive list and a few others, such as IL&FS Environment, also operate RDF facilities. A total of 80 per cent of these plants are delivering RDF to cement kilns, while a few are providing RDF to existing WtE facilities and a few are in the process of establishing WtE plants close to the RDF plants. These plants handle 24,250tpd of MSW and produce 5100tpd of RDF (yield of ~21 per cent). Several RDF production facilities have shut down in the last few years – for example, the plants operated by Hanjer Biotech in several cities and A2Z Infrastructure. Zigma Global Environ Solutions (Zigma) is currently one of the leading providers of landfill mining services and one of the largest suppliers of RDF to the cement plants. The company has already reclaimed several acres of land.

Figure 2: waste composition in two of the biggest dumpsites in India



Waste composition in Mulund (Mumbai) dumpsite [12]

Waste composition in Ghazipur (Delhi) dumpsite [13]

Landfill mining as a source of SCF/RDF

Landfills and dumpsites occupy valuable space close to urban areas, lead to health risks in surrounding areas and are enormous reserves of resources with potential for recycling or RDF production. By landfill mining, recyclables and combustibles can be extracted from the dumped waste, leading to improved resource utilisation and land reclamation, and a prolonged lifespan of the landfill or dumpsite.

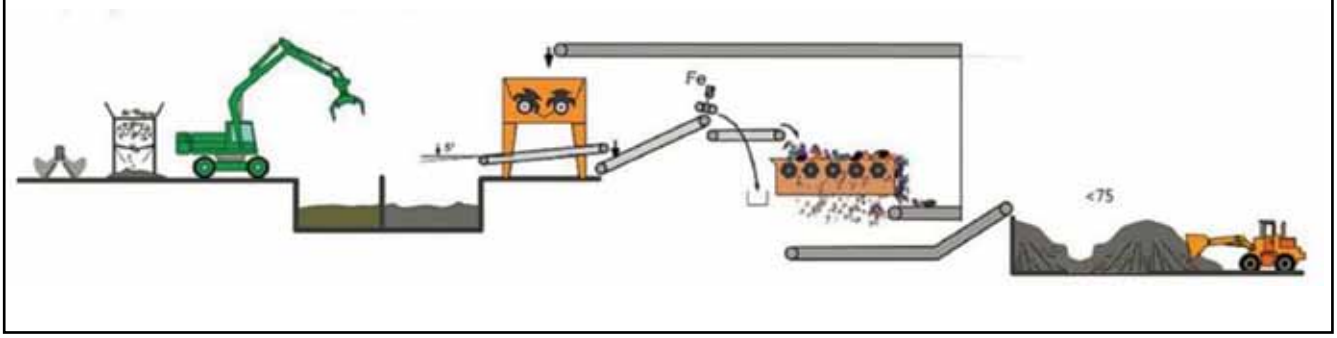
There is no standard way of performing landfill mining, and the landfill mining should be designed in line with demand and available treatment options. In Europe advanced treatment infrastructure, regulations and funding schemes are in place, making enhanced landfill mining with utilisation of multiple waste fractions a popular option. In India similar infrastructure and policy are not available, and simpler landfill mining with a focus on combustibles, easily recoverable recyclables and compost is more common. The process usually involves simple on-site pretreatment of the waste with manual extraction of some recyclables and mechanical sieving to separate larger

Table 2: RDF and SCF utilisation in the Indian cement industry (data collected by CII-GBC)

SN	Cement producer – cement plant	Refuse-derived fuel (RDF)			Segregated combustible fraction (SCF)		
		Volume (t)	Calorific value (kcal/kg)	Heat (10^6 kcal)	Volume (t)	Calorific value (kcal/kg)	Heat (10^6 kcal)
1	ACC Ltd – Kymore	18,596	2482	46,155			
2	ACC Ltd – Wadi*	28,152	2357	66,362			
3	Ambuja Cement Ltd – Maratha*	41,212	2500	103,030			
4	Ambuja Cement Ltd – Rabriyawas				13,724	3632	49,846
5	Ultratech Cement Ltd – Reddipalayam	2233	4875	10,886			
6	UltraTech Cement Ltd – Kovaya	910	3126	2845			
7	UltraTech Cement Ltd – Rajashree	334	1893	632			
8	UltraTech Cement Ltd – Kotputli*	266	4728	1258			
9	JK Cement – Muddapur*	13,520	3285	44,413	10,680	2135	22,802
10	JK Cement – Mangrol*	1476	5661	8356	19	3561	68
11	Dalmia Cement (B) Ltd – Dalmiapuram*	7648	3784	28,940	48	3238	155
12	Dalmia Cement (B) Ltd - Kadappa*				212	3423	726
13	Dalmia Cement (B) Ltd - Ariyalur*	3465	3795	13,150			
14	JK Lakshmi Cement Ltd – Sirohi*	62	2866	177	69,437	2802	194,541
15	Birla Corp Ltd				9	2885	26
16	Kesoram Industries Ltd	71	2500	178			
	Total	**117,944**	**2205**	**326,381**	**94,128**	**2849**	**268,162**

** data from 2019-20, other data from 2018-19*

Figure 3: diagram of preprocessing facility at ACC's Wadi cement plant



recyclables and combustibles, and smaller parts, consisting of soil-like material, organic waste, inert and mixed smaller waste (see Figure 2).

Zigma operates at 11 sites in Tamil Nadu (Erode – multiple sites, Trichy, Tambaram, Pallavaram, Karur and Karaikudi), Andhra Pradesh (Vijayawada and Tirupati), Gujarat (Vadodara), Maharashtra (Nagpur) and Uttar Pradesh (Noida). The technology aims at stabilising, processing, segregating and responsibly disposing the aggregates, thus reclaiming the land. The company is processing 9500t of MSW everyday, thereby producing 2375t of RDF (yield: 25 per cent). The current sites where this technology is now operating are expected to contain >10Mt of legacy waste.

Current utilisation of RDF and plastic waste in the Indian cement industry

About 1.6Mt of AFs were used in the Indian cement industry in 2017. The number of cement plants using AFR has increased from 12 plants in 2010 to 61 plants in 2017. The MSW-based SCF/RDF use in cement kilns is currently limited to an equivalent of 0.6 per cent of thermal substitution.[10] CII-GBC gathered information of AFR utilisation from 40 cement plants, showing that 16 of them were using RDF/raw MSW (see Table 2). The total RDF and raw MSW used was 212,073t with heat value of 0.6 x 10^{12} kcal.

Geocycle India, the waste management business of ACC Ltd and Ambuja Cement Ltd, has co-processed >100,000t of RDF and SCF in 2019-20 (see Table 2) and plans to use more than 250,000t in 2021.

Around 46 of the country's 238 plants are currently using some amount of plastic, but the MoHUA is in talks with the Cement Manufacturers Association to increase the amount of plastic disposed at cement plants.

Capital and operational expenditure for RDF production and utilisation in cement kilns

The capital expenditure (capex) for setting up a 500tpd MSW processing plant typically varies in the range of INR170-200m (US$2.29m-2.69m).[14] This works out to be INR340-400/t of waste handled.[15] Operation and maintenance costs (opex) are in the range of INR120-290/t.[15] Lower costs apply to larger facilities.

As most of the plants use the same installations to produce different products, cost allocation principles need to be applied for determining the cost of different recycled products, such as RDF. As per the data provided by IL&FS Environment, one of the private sector companies with multiple facilities, the capital cost for a 100tpd plant for providing 50mm size RDF is INR125m while the operation and maintenance cost for the same plant is approximately INR1150/t (see Table 3). However, these costs can vary significantly by location.

The expert committee that drafted the RDF guidelines recommended that the price of RDF should be dynamic and linked to the cost of coal. Considering INR0.40/1000kcal as the commercially-acceptable price of properly-processed RDF, the committee recommended minimum and maximum prices for different grades.[10] While recommending the cap and floor prices, the committee noted that in the long-term the prices will be established by market forces. The mentioned price would be for the <50 mm size material that is suitable for co-processing in a cement plant's in-line calciner (ILC). For a separate line calciner (SLC), the price will be cheaper and can be negotiated between the RDF operator and the cement plant. The committee also suggested that the cement plant bears the cost of transportation up to 100km, but between 100-400km the cost will be borne by the relevant ULB. The cost of transportation decreases with increase in distance and reverse haulage options.

Incremental capital investment in cement plants is required to enable use of RDF including for the receiving facility, discharging facility, laboratory, storage, feeding system, conveyor system, etc. The capex for a conventional mechanised hopper system is INR55m and for advanced automated feeding systems is INR200m.[10] CMA (2018) estimates the capex for installing a 100tpd RDF feeding system to be INR150m.[15] The pre-processing/pre-treatment cost of waste is estimated to be INR0.30/1000kcal and the co-processing/feeding cost of waste is estimated to be INR0.30/1000kcal. There is also the extra cost of lost clinker due to high moisture content and the cost of additional limestone to mitigate the effect of high ash content, etc. These additional costs are estimated to be INR0.20/1000kcal.[15]

Table 3: indicative capital and operational expenditure for RDF production plant[10]

Expenditure	≤100tpd	100-200tpd	200-300tpd
Capital expenditure – RDF size 25mm (INRm)	153	342	448
Operational expenditure – RDF size 25mm (INR/t)	1390	1870	1851
Capital expenditure – RDF size 50mm (INRm)	125	216	295
Operational expenditure – RDF size 50mm (INR/t)	1150	1200	1280

Co-processing potential for RDF and plastic waste

India has the world's second-largest cement industry, accounting for eight per cent of world production. Installed capacity exceeds 500Mta and production is over 330Mta. Estimated coal consumption

is more than 55Mta. India has the most energy-efficient cement plants in the world. However, recovery of wastes and replacement of coal in the cement industry is a relatively-new concept with few adopting it. Therefore, while the sector's thermal substitution rate (TSR) increased from 0.6 per cent in 2010 to four per cent in 2017, the figure remains low. This compares to a EU average of almost 40 per cent, and 70 per cent or higher in Norway.

The expert committee also made other important recommendations such as requiring all cement plants located within 400km from a solid waste-based RDF facility to make necessary arrangements to utilise the fuel in the following phase-wise manner, subject to availability:[10]

- substitute at least six per cent of fuel by segregated combustible fraction (SCF) and RDF, within one year from the date of amendment of the Solid Waste Management (SWM) Rules (2016)
- substitute at least 10 per cent of fuel by SCF and RDF, within two years from the date of amendment of these rules
- substitute at least 15 per cent of fuel by SCF and RDF, within three years from the date of amendment of these rules.

To facilitate such a transition, the committee also suggested the utilisation of part of corporate social responsibility (CSR) funds to cover transportation costs, consistent with the provisions under the CSR Rules prescribed under the Companies Act, 2013. Another suggestion was to increase the cement bag price in the range of INR0.40-1.85/50kg bag [10], an increase of less than 0.5 per cent per bag, with certain assumptions of costs and revenues, to reduce the payback period from a typical >7 years to 4-5 years.

CII-GBC has created a roadmap for the Indian cement industry to achieve 25 per cent TSR by 2025, which will help India in meeting its intended nationally determined contributions (INDC) target. To achieve 25 per cent TSR by 2025, the Indian cement industry requires 7.07Mt of oil equivalent (Mtoe) energy from AF (one Mtoe = 10^{13}kcal). By achieving 10 per cent TSR, the cement industry can co-process more than 8Mta of plastic wastes containing SCF/RDF. By 2025 600Mt of cement production is anticipated, with 14.19 per cent of the heat requirement to come from MSW/RDF.[16]

During World Environment Day 2018, hosted by India under the theme of 'Beat Plastic Pollution', the country's cement industry pledged to co-process 12Mta of plastic waste by 2025. MoEFCC noted that processing various plastic wastes in cement kilns could go a long way to solving the problems.[17]

Conclusion and way forward

Unless urgent steps are initiated by all stakeholders, particularly by the government and cement companies, achieving the TSR target will be challenging. Given that almost two years have elapsed since the RDF guidelines were published, the stakeholders need to reconvene and work together towards increasing the RDF utilisation. A more constructive approach of finding middle ground is the need of the hour. Previous experience, such as enhancing usage of fly ash in the construction industry, integrating higher renewable energy into the power grid, achieving CO_2 emission intensity reduction of 21 per cent between 2005 and 2014,[18] amongst other examples, suggests that the Indian industry has the capability to rise to the occasion.

A working group has been convened by CII-GBC under this project to discuss and attempt demonstration of significantly higher utilisation of RDF (equivalent to 5-10 per cent TSR) in select cement plants to generate lessons, develop business models and policy implications for wider replicability, based on scientifically-established evidence.

CMA, as a representative of the Indian cement industry, has expressed certain reservations such as that only Grade-II and Grade-I RDF will be acceptable to the cement plants, and the transportation costs for providing RDF to the cement plants must be borne by the ULB. The ULBs need to supply RDF to the factory gate, against a long-term non-revokable supply agreement, to ensure the recovery of investment in capex for co-processing.[15] CMA also suggested that a two-year pilot project can be commissioned by relevant ministries, research institutes and cement companies to ensure regular and consistent supply of the required quality of RDF delivered to the cement plant. ■

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