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Report

Climate Resilience and Finance for Urban Sustainability

Cost Recovery Business Models for enhancing utilization of Segregated Combustible Fraction and Refuse Derived Fuel (RDF) from Municipal Solid Waste

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Summary

The report presents four cost recovery business models for managing segregated waste (SCF and RDF) based on the 'Polluter Pays' Principle. The report highlights the financial cost associated with waste management and the importance of acknowledging and paying for it.

The four cost recovery models evaluate different options for recovering the cost of managing waste using two different technologies (co-processing in a cement plant and waste to energy). The report acknowledges that market inefficiencies, inadequate regulation, and practical considerations can result in the adoption of costlier choices.

However, the society is best off when the least cost approach is adopted. The report evaluates three options for deploying cement kilns due to lower overall cost and technological advantages. It is also noted that the RDF production facility can be located within or close to the city or the cement facility. The report concludes that the four options presented in the report are comprehensive from a results perspective.

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Abbreviations

ADB	Asian Development Bank
AF	Alternative Fuel
AFR	Alternative Fuel and Raw material
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
CCS	Carbon Capture and Storage
CAPEX	Capital Expenditure
CEMS	Continuous Emission Monitoring System
CERC	Central Electricity Regulatory Commission
CII-GBC	Confederation of Indian Industry -Sohrabji Godrej Green Business Centre
CPHEEO	Central Public Health and Environmental Engineering Organisation
CMA	Cement Manufacturers Association
CPCB	Central Pollution Control Board
CSE	Centre for Science and Environment
CSR	Corporate Social Responsibility
CV	Calorific Value
DIPP	Department of Industrial Policy and Promotion (now Department for Promotion of Industry and Internal Trade- DPIIT) under Ministry of Commerce and Industry (MoCI)
EC	European Commission
EPR	Extended Producer Responsibility
EU	European Union
FGT	Flue Gas Treatment
GGGI	Global Green Growth Institute
GHG	Green House Gas
INDC	Intended Nationally Determined Contribution
INR	Indian Rupees
IPCC	Intergovernmental Panel on Climate Change
ISWM	Integrated Solid Waste Management
IRR	Internal Rate of Return
kcal	Kilocalories
ktpa	kilo tonnes per annum ('000 tonnes)
kwh	kilo watt hour

MBT	Mechanical Biological Treatment (for RDF production)
MNRE	Ministry of New and Renewable Energy
MoCI	Ministry of Commerce and Industry
MoEF&CC	Ministry of Environment and Forests & Climate Change
MoHIPE	Ministry of Heavy Industries and Public Enterprises (Now Ministry of Heavy Industries- MoHI)
MoHUA	Ministry of Housing and Urban Affairs (Earlier known as Ministry of Urban Development- MoUD)
MRF	Material Recovery Facility
MSW	Municipal Solid Waste
Mt	Million tonnes
Mtpa	Million tonnes per annum
MW	Mega watt
NCV	Net Calorific Value
NCCBM	National Council for Cement and Building Materials
OPEX	Operational Expenditure
PCC	Pollution Control Committees
PIB	Press Information Bureau
PPP	Public Private Partnership
RDF	Refuse Derived Fuel
SBM	Swachh Bharat Mission (Clean India Mission)
SBM(U)	Swachh Bharat Mission (Urban)
SCF	Segregated Combustible Fraction
SLF	Sanitary Landfill Facility
SPCB	State Pollution Control Boards
SRF	Solid Recovered Fuel
SUDD	State Urban Development Departments
SWM	Solid Waste Management
TPD	Tonnes Per Day
TPH	Tonnes Per Hour
TSDF	Treatment, Storage and Disposal Facility
TSR	Thermal Substitution Rate
ULBs	Urban Local Bodies
VGF	Viability Gap Funding
WtE	Waste-to-Energy

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Plastic will be the main ingredient of all our grandchildren's recipes.

~ Anthony T. Hincks

Source: unsplash

Glossary

Ash residues
Left-over material from a combustion process. They may take the form of fly ash or bottom ash. Bottom ash is primarily a toxic residue of incineration made from agglomerated ash particles that are too large to be carried in the flue gases and fall through open grates to an ash hopper at the bottom of the furnace. Fly ash is highly toxic particulate matter captured from the flue gas of an incinerator by the air pollution control system.

Baler
A machine used to compress recyclables into bundles to reduce volume. Balers are often used for newspaper, plastics, and corrugated cardboard.

CAPEX
Capital expenditures (CAPEX) are funds used by a company to acquire, upgrade, and maintain physical assets such as property, plants, buildings, technology, or equipment. CAPEX is often used to undertake new projects or investments by a company.

Closed loop recycling
Materials such as metals, paper, glass, certain plastic types to be recycled ultimately end up in a production process and manufacturing system that manufactures materials or products like those that were originally produced, used, and disposed.

Combustibles
Inflammable materials in the waste stream, including paper, plastics, wood, food, and garden wastes.

Consumer Price Index (CPI)
It is a measure of the average change over time in the prices paid by urban consumers for a market basket of consumer goods and services.

Co-processing
Utilisation of alternative fuel and raw materials in the resource and energy intensive industries (for example, in cement kilns) for energy and resource recovery.

Circular economy
A circular economy is a regenerative system in which resource input and waste, emission and energy leakage are minimized through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, recycling, and upcycling. This contrasts with a linear economy which is a 'take, make, dispose' model of production.

Disposal
The final and safe disposal of solid waste to prevent contamination of groundwater, surface water, ambient air and attraction of animals and birds.

Dumpsites
A land utilised by urban local bodies for unscientific disposal of municipal solid waste without following the principles of sanitary landfilling.

(Energy) recovery
Any operation the principal result of which is waste serving as alternative fuels by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy. This could be co-processing of waste in the local industry.

Equity risk premium
For an investor to invest in a stock, the investor has to be expecting another return than the risk-free rate of return; this additional return is known as the equity risk premium because this is the additional return expected for the investor to invest in equity.

Extended Producer Responsibility
Means responsibility of any producer of electrical and electronic equipment, for their products beyond manufacturing until environmentally sound management of their end-of-life products.

Incineration

Burning of certain types of solid, liquid, or gaseous materials; or a treatment technology. In a mass-burn incinerator, solid waste is burned without prior sorting or processing.

Inerts

Wastes which are not bio-degradable, recyclable or combustible and include non-recyclable fraction of construction and demolition waste, street sweeping or dust and silt removed from the surface drains.

Integrated Solid Waste Management (ISWM)

ISWM refers to a strategic initiative for the sustained management of solid waste using a comprehensive integrated format generated through sustained preventive and consultative approach to the complementary use of a variety of practices to handle solid waste in a safe and effective manner.

Internal Rate of Return (IRR)

IRR is the interest rate at which the net present value of all the cash flows i.e., receipt and expenses from a project/ investment over the designed life of a plant, equal zero.

Landfill

Landfill means a waste disposal site for the deposit of the waste onto or into land (including underground). An approved landfill site is approved by local or national authorities through a permit or is the generally accepted method for disposal of waste, excluding informal dumping of waste. It may or may not be environmentally sound.

Landfill mining

The process of removing reusable resources from old landfills for recycling.

Marginal Cost of Funds based Lending Rate (MCLR)

It is the minimum lending rate below which a bank is not permitted to lend.

Material recovery facility (MRF)

A facility where non-combustible solid waste can be temporarily stored by the urban local body or any person authorised by the urban local body to facilitate segregation, sorting and recovery of various components of waste by informal sector of waste pickers or any other work force engaged for the purpose before the waste is delivered or taken up for its processing or disposal.

(Material) Recycling

Any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations (ref: EU Waste Framework directive).

Municipal Solid Waste (MSW)

Includes domestic waste, commercial waste, institutional waste, market waste and other non-residential wastes, street sweeping waste, silt removed/collected from surface drains, horticulture waste, construction, and demolition (C&D) waste and treated bio-medical waste excluding industrial hazardous waste, and E-waste generated in any municipal authority area in either solid or semi-solid form.

Open Dump

An unplanned “landfill” that incorporates few, if any of the characteristics of a controlled landfill. There is typically no leachate control, no access control, no cover, no management, and many waste pickers.

OPEX

An operating expense is an expense that a business incurs through its normal business operations. Operating expenses include rent, equipment, inventory costs, marketing, payroll, insurance, and funds allocated for research and development.

Prevention

Waste prevention or reduction is considered the most effective approach to waste management as it addresses the root cause of waste generation. By taking measures at the design, production, or use stage, the amount of waste generated can be minimised.

Recovery

Recovery is another waste management strategy that focuses on using waste as a resource. It involves substituting other materials or fuels with waste, which can help conserve natural resources and reduce greenhouse gas emissions. Co-processing is a form of recovery that is used in cement production to recycle waste materials, such as hazardous waste or municipal solid waste, and recover their energy value.

Recycling

Recycling is an important strategy for managing waste that has already been generated. It involves reprocessing waste into new products or materials, which helps conserve natural resources and reduces the amount of waste that ends up in landfills or incinerators.

Refuse Derived Fuel (RDF)

RDF is produced from various types of wastes such as municipal solid waste (MSW), plastic waste or industrial waste. Selected waste and by-products with recoverable calorific value can be used as fuels in a cement kiln, replacing a portion of conventional fossil fuels, like coal, if they meet strict specifications. Sometimes they can only be used after pre-processing to provide 'tailor-made' fuels for the cement process.

Residual waste

Includes the waste and rejects from the solid waste processing facilities which are not suitable for recycling or further processing.

Reuse

Reuse is another effective strategy of waste management as it extends the life of products or components and reduces the need for new ones.

Segregation

Sorting and separate storage of various components of solid waste namely biodegradable wastes or wet waste, non-biodegradable wastes or dry waste including recyclable waste, combustible waste, sanitary waste and non-recyclable inert waste, domestic hazardous wastes, E-waste and construction and demolition wastes.

Source Segregation

The segregation of specific materials at the point of generation for separate collection.

Tipping fee

Tipping fee or support price determined by the urban local body, or any state agency authorised by the state government to be paid to the concessionaire or operator for handling one or more components of solid waste. It is different from 'User fee' which is imposed through a byelaw by the urban local body on the waste generator.

Urban Local Body

Includes the municipal corporation, nagar nigam, municipal council, nagar palika, nagar palika parishad, municipal board, nagar panchyat, town panchayat, notified area committee or any other local body constituted under the relevant statutes where management of solid waste is entrusted to such agency including the body in notified industrial township, notified area, villages declared outgrowth in urban agglomeration by the Registrar General and Census Commissioner of India from time to time.

Viability Gap Funding

Financial support determined by the urban local body or authorised state government or central government agency to be paid to the concessionaire or operator of a solid waste processing facility based on the output quantity of compost, biogas produced, or energy or power generated to cover or partly cover the difference between market price of the output and its production cost plus reasonable profit margin.

Waste-to-energy (WtE) plant

These facilities consist of large incinerator-type operations where waste is incinerated (burned). The heat from this combustion process is converted into high-pressure steam, which can be used to generate electricity for sale to public utility companies under long-term contracts. The residue from the incineration process is disposed of in a landfill.

Waste management hierarchy

The waste hierarchy is a priority order in waste prevention and management legislation and policy. Prevention, reuse, and material recycling is normally the preferable option, except in cases for hazardous waste and POPs waste where destruction might be required. Landfilling is the least preferred option and should be limited to a minimum. Prevention includes measures taken before a substance, material or product becomes waste.

Wholesale Price Index (WPI)

It is the price of a representative basket of wholesale goods. Some countries (like the Philippines) use WPI changes as a central measure of inflation. But now India has adopted the new CPI to measure inflation.

Working Capital

Working capital is the money used to cover all of a company's short-term expenses, which are due within one year. Working capital is the difference between a company's current assets and current liabilities. Working capital is used to purchase inventory, pay short-term debt, and cover day-to-day operating expenses.

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We are living on this planet as if we have another one to go to.

~ Terri Swearingen

Source: RTI

Executive Summary

The total MSW generated in urban India is estimated to be between 50-65 million tonnes per annum, and the generation of MSW is growing at an annual rate of 5%. Some independent estimates though point to a significantly higher waste generation. The per capita waste generation is estimated to be 120 grams per day, and waste collection efficiency is 95.4%. Out of the collected waste, about 52% is treated and 19% is landfilled. The remaining, slightly less than a third of the total, is either not collected or even when collected, is untreated and unaccounted.

Untreated waste has significant climate impacts. It is therefore important to integrate climate considerations in waste management policies and broader urban planning frameworks.

Swachh Bharat Abhiyan (Clean India Mission) is enabling progress in this area. According to the latest SBM (U) data, door-to-door collection of waste is complete in 96% of the wards, and the overall waste treatment rate has improved 60%. However, the overall situation remains below par compared to global benchmarks as well as some of the emerging countries. Thus, we have a long road ahead and there is a need for collective effort from citizens, government, and other stakeholders to enhance sustainability and climate resilience.

A significant way to enhance sustainability is to recover material and energy from non-recyclable waste stream. Deployment of co-processing and/or Waste to Energy (WtE) for non-recyclable waste through refuse-derived fuel (RDF) or segregated combustible fraction (SCF), are two options. Both are better compared to landfilling or open dumpsites. Between the two, co-processing in cement kilns is the preferred option for its potential for material recycling and energy recovery, as well as its cost efficiency and low GHG emissions. Adoption of waste hierarchy, based on circularity, will be key to the goal of zero waste and enhancing climate resilience in cities.

Given the advantages of co-processing in cement kilns, it has been adopted extensively in Europe and is expanding to other parts of the world, such as Southeast Asia and China. Countries with a mature waste management system, smooth permitting procedures, a modern cement industry, and high prices of fossil fuels have higher rates of co-processing.

Following the global practice, attempts have also been made in India to adopt co-processing given that India is amongst the leading producers of cement globally. Several pilots have been conducted and some of the leading companies are using significant quantities already. However, overall Thermal Substitution Rate is relatively low, i.e., below 5% at industry level.

In 2017-18, an expert committee formed by MoHUA deliberated on sustainability of using waste as fuel in cement kilns in India. It also identified issues and challenges within the supply chain framework that could affect the success of this strategy and made several recommendations. The report was widely discussed, appreciated and released by the Minister for Housing and Urban Affairs on occasion of Gandhi Jayanti in 2018. However, the recommendations and standards proposed by the committee are yet to be fully adopted, which partly explains the limited use in India. Without a supportive regulatory framework, it may be difficult for businesses to invest in the infrastructure and technology necessary to make co-processing of waste a sustainable and viable option.

One of the key barriers identified by the committee was the consistency and availability of usable material (RDF or SCF), to increase co-processing. This is so because the composition of RDF can vary widely depending on the area, the seasons, the organisation of collection, the food standards of the city, and other factors. In India, the usual yield of RDF from mixed MSW is relatively low, in the range of 15%-30%, although a higher yield may possibly be achieved if overall waste management is improved. Nevertheless, the committee prescribed certain standards and guidelines regarding SCF and RDF of different quality.

The Indian cement industry has the potential to significantly contribute to waste management and reduction of greenhouse gas emissions by co-processing alternative fuels, particularly RDF, in cement kilns. While there are challenges in terms of the quantity and quality of SCF or RDF available, as well as logistics and capacity issues, some progress is evident. More importantly, the industry has set ambitious targets for the future.

To sustainably increase co-processing, the agreements between cement companies and ULBs should be fair and transparent. Further, it is critical that the interests of other stakeholders, such as society at large, and the environment and public health, are safeguarded. At the same time, it is crucial to recognise the valuable contribution that the cement industry can make towards waste management and reduction of greenhouse gas emissions, and to support and encourage the development of this industry in a responsible and sustainable manner.

This report is an attempt to present four cost recovery business models for managing segregated waste such as SCF and RDF using two different technologies (cement kilns and waste to energy). While the details matter, two crucial points need to be recognised upfront.

Firstly, waste management incurs a financial cost that has historically been overlooked, resulting in significant environmental and social costs. Secondly, the cost of managing waste should be borne by the polluter, following the 'Polluter Pays' Principle.

In the context of waste management, the polluter is the waste generator, which is typically the consumer or society at large. Further, it is also reasonable to assume that the amount of waste generated per capita is directly proportional to income.

The key assumptions used in four cost recovery models for waste management, includes CAPEX and OPEX estimates for RDF production, co-processing, and waste to energy facilities, as well as financing assumptions such as the cost of debt, cost of equity, and debt-to-equity ratio. The analysis also considers transport cost of SCF and RDF, with higher estimates used due to an increase in crude oil prices in 2022. The assumptions are based on MoHUA guidelines and industry estimates and are adjusted for inflation and annual escalation rates.

A typical city with MSW generation of 500-1000 tonnes per day is assumed for this analysis, and some numbers pertaining to Agra are used purely for illustrative purposes. The actual costs will vary from one city to another depending on market conditions, credit ratings, and other factors, and it is recommended to conduct thorough analysis and research before arriving at actual costs.

The report acknowledges that market inefficiencies, inadequate regulation, and practical considerations can result in the adoption of costlier choices. However, the society is best off when the least cost approach is adopted.

The models involve producing refuse-derived fuel (RDF) from municipal solid waste and co-processing it in cement kilns or using it as fuel in waste-to-energy facilities. For this report SCF or RDF is assumed to be sourced from incoming stream of waste. It is also possible to source SCF or RDF from land mining of legacy waste. Therefore, a brief section on Material Recovery Facilities and land mining have been included.

The report evaluates three options for deploying cement kilns due to lower overall cost and technological advantages. It is also noted that the RDF production facility can be located within or close to the city or the cement facility.

The costs associated with RDF production and processing are recovered through different mechanisms such as passing it onto cement consumers, households in the city as a waste management charge, property owners through a property surcharge, or electricity consumers in proportion to the energy consumed.

A motivation for implementing one or more of these cost recovery business models is to address the challenge of inadequate financing, which is typically a major constraint for urban local bodies. Implementation of one of more of these options will improve finances over a period, but immediate capital is required to invest in waste management. Therefore, the report also presents two alternative options to access funding for the upfront investment required.

First is to increase the use of public-private partnership (PPP) mechanism. Policy makers and administrators have been recommending PPPs as an alternative funding source for various reasons including the sub-optimal performance of ULBs in developing and managing projects. PPPs offer benefits such as access to capital and commercial motivation, but historically, managing these contracts has been challenging, often resulting in litigation. The report therefore also offers some suggestions to improve PPPs in SWM sector, based on the recommendations of the Kelkar Committee.

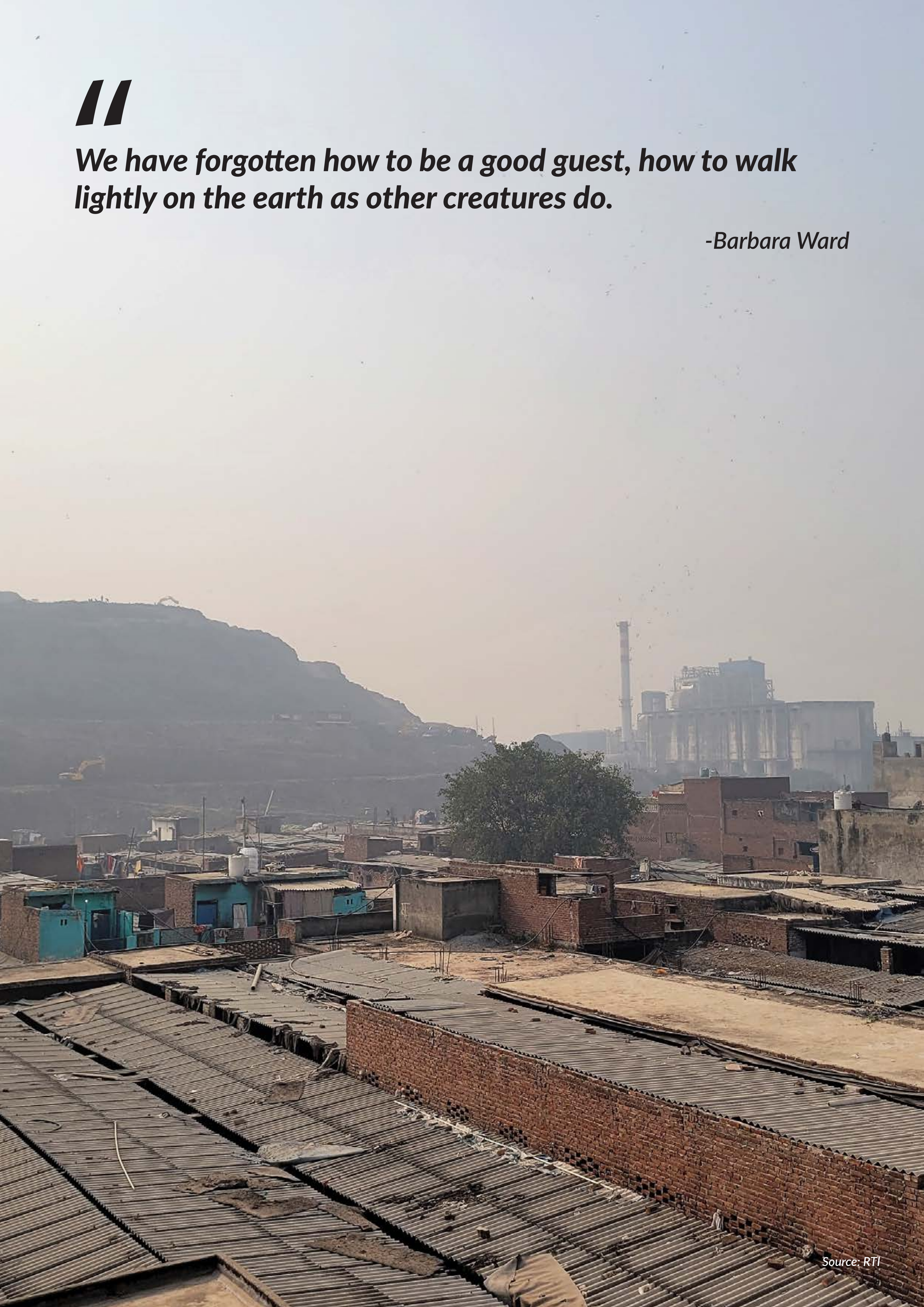
Second mechanism is to tap international climate funds. Given the increasing climate risk profile of Indian cities and the need to focus on adaptation and resilience, a brief introduction to international climate funds such as GCF is included. Additionally, development banks such as the World Bank and ADB also support waste management, energy recovery and climate mitigation projects. Co-processing and WtE can access funding through these mechanisms as well.

Overall, the four cost recovery business models are aligned to the 'Polluter Pays' Principle and well placed to enhance stakeholders' ability to invest in waste management and co-processing. All four models are economically viable, with relatively modest cost increases for consumers, and potential savings from coal substitution. Implementing one or more of these models will enable stakeholders to access financing, both domestic and international, for required investments.

One or more of these models may be applied at the city level based on the context. Some adjustments based on local circumstances may be required to ensure that the costs are allocated in a fair, equitable and transparent manner. Overall, the comparative analysis provides valuable insights into the different cost recovery mechanisms for solid waste management in cities. The four options presented in the report are therefore comprehensive from a results perspective.

"We have forgotten how to be a good guest, how to walk lightly on the earth as other creatures do.

-Barbara Ward



Source: RTI

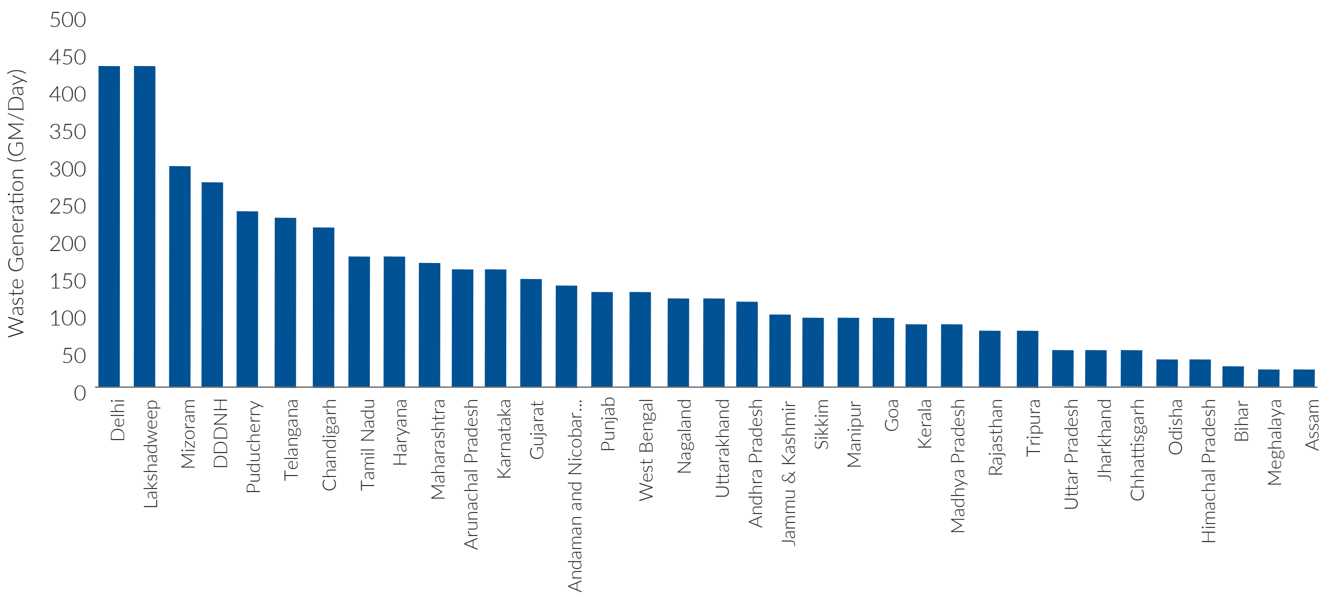
1 Waste Management Scenario

Municipal Solid Waste (MSW) is a heterogeneous mixture of paper, plastic, cloth, metal, glass, organic matter, dust, etc., generated from households, commercial establishments, markets, and road cleaning activities. Government data from different agencies suggests that the total municipal solid waste (MSW) generated in urban India is between 50-65 million tonnes per annum (Mtpa).

CPCB estimates it to be 58.5 Mtpa (CPCB, 2021), according to the CPHEEO of the Ministry for Housing and Urban Affairs (MoHUA), the figure is 62 Mtpa (CPHEEO, 2018), while SBM(U) 2.0 suggests 48 Mtpa (MoHUA, 2021). It is estimated that the generation of MSW is growing at an annual rate of 5% (Ministry of Finance 2009, cited in CPHEEO report, 2018). A World Bank report estimates a significantly higher waste generation of 277 Mtpa for pan India (rural and urban), which is projected to increase further to 387.8 Mtpa by 2030 (World Bank, 2018).

On per capita basis, CPCB estimates suggest waste generation to be 120 gram per day (refer to Figure 1.1 for state wise details). SBM (U) 2.0 Operational Guidelines 2019 suggests a range from 300 grams per day for smaller cities (pop<100,000), 450 grams per day for cities with population between 0.1 to 1 million and 550 grams per day for bigger cities (pop>1million).

Figure 1.1: State-wise municipal solid waste generation in gram per capita per day in 2020-21



Source: Annual Report on implementation of SWM Rules 2016 (CPCB, 2021)

As per CPCB, the waste collection efficiency is 95.4%. Of the waste collected, about 52% treated and 19% is landfilled. The remaining, slightly less than a third of the total, is either not collected or even when collected, is untreated and unaccounted (CPCB, 2021).

As per the latest SBM (U) data, 100% door-to-door collection of waste is now achieved in 96% of the wards and the overall waste processing rate is 60% (SBM (Urban), 2023). Though the waste treatment rate has increased over the last five years from 19% in 2015-16 to 50% in 2020-21 (CPCB, 2021), it is relatively low compared to global figures (refer section 4 for details).

Untreated municipal waste dumped in various cities is a significant challenge for cities as it results in significant environmental and public health issues. Dumpsites are also a source of Methane, a potent Green House Gas (GHG). Further, large pieces of valuable urban land are locked up in an unproductive and unhygienic activity. According to the Planning Commission, about 1240 hectares of precious land is being lost every year to dispose solid waste (Singh, 2022).

It is estimated that more than 10,000 hectares of valuable urban land is locked up under 3,159 legacy waste dumpsites as per the National Green Tribunal estimates (Singh, 2022). The number of dumpsites increased to 3184 as per the latest CPCB data (CPCB, 2021). A visit to three dumpsites in Delhi revealed a serious picture of (refer to Figure 1.2) continued environment and health challenges. Efforts in the last couple of years have been initiated to remediate the waste mountains in the city and in other large metros in the country.

Figure 1.2: Ghazipur landfill in Delhi

Source: RTI

Guidelines for rehabilitation of old dumpsites were detailed in the SWM Rules 2016 under clause 'J' of Schedule–I. Further to the NGT directive, CPCB released the Guidelines for Disposal of Legacy Waste in 2019 (CPCB, 2019). SBM 2.0 has provided a clear mandate to cities to remediate the existing legacy waste dumpsites. Further to that, various states have initiated remediation measures at landfill sites (PIB, 2022) (The Hindu, 2022). In 2022, MoHUA has approved action plan for remediating 1,000 legacy dumpsites, containing 128 million tonnes of waste under SBM (U), with a total project cost of more than ₹ 8,000 crore (PIB, 2022).

As per SBM (U) 2.0 dashboard, Maharashtra and Karnataka have the highest amount of waste remaining to be remediated, 38.2 and 18.3 million tonnes, respectively. Telangana and Chhattisgarh have been leading other states in waste remediation (refer to Table 15.1 in Annexure) (SBM (Urban), 2023).

Untreated waste has significant climate impacts due to GHG emissions, particularly Methane, which has a 100-year global warming potential 28-34 times that of CO2; measured over a 20-year period, that ratio grows to 84-86 times. Methane produced at these dumpsites contributes approximately 3% to 4% to the annual global anthropogenic greenhouse gas emissions (IPCC, 2001 cited in CPCB, 2019).

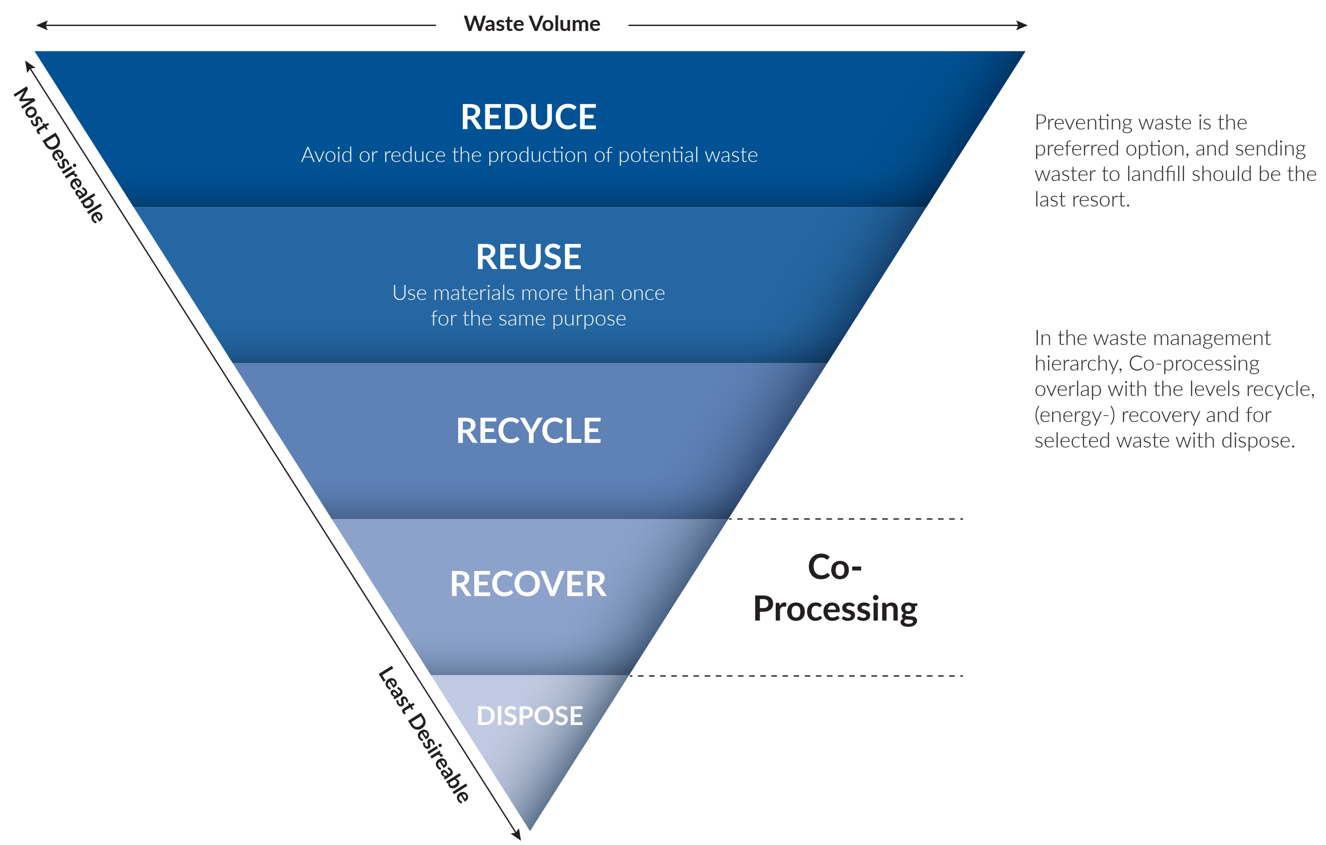
Further, untreated dumpsites have a large footprint on local air, water, and land pollution. Besides polluting the air and surface water, the leachate discharge from these dumpsites also pollutes the groundwater irreversibly.

According to a Planning Commission task force report in 2014, of the 62 Mt of MSW generated in urban India, 12 Mt (19%) is combustible fraction which can be potentially converted into refuse-derived fuel (RDF), thereby replacing 8 Mt per annum of coal, equivalent to 15%-16% of coal used in the Indian cement industry (Saha, Karstensen, Vairavan, & Balakumar, 2017).

Of the total MSW, the largest proportion is the biodegradable component (around 40%-70%) while the remaining non-biodegradable share comprising both recyclable and non-recyclable dry waste varies between 20%-40% across cities (CSE, 2018). A part of the non-biodegradable component is plastic waste. As per CPCB's Annual Report on Implementation of Plastic Waste Management Rules, 2016, plastic waste in India is estimated to be more than 3.4 Mtpa in 2019-20 (CPCB, 2020), i.e., at-least 5% of the total waste.

Given India's commitment to net-zero by 2070 and an increasing amount of waste generation, it is critical to integrate climate considerations in policy and programmatic solutions to waste management as well as broader urban planning framework for cities. While untreated waste and associated dumping represent a big challenge, the other side of the coin is the resource that it represents, if managed scientifically. The gold standard for waste management strategy for a city is to adopt waste hierarchy based on circularity, as demonstrated in the figure 1.3.

Figure 1.3: Waste Hierarchy developed by the European Union's Waste Framework Directive



Source: GIZ-LafargeHolcim. (2020)

Consistent with the circularity principles, the SWM Rules 2016 prescribe that non-recyclable waste, including plastic, with calorific value exceeding 1500 kcal/kg or more, should not be disposed of at landfills or dumpsites, but used for generating energy through WtE (Waste to Energy) or co-processing. The priority order prescribed in the EU Waste Framework Directive, i.e., Directive 2008/98/EC prescribes the following order: prevention, preparing for reuse, recycling, other recovery (e.g., energy recovery) and disposal in landfills (Antico, 2020). The SWM Rules 2016 are broadly consistent with the waste hierarchy (refer to Figure 1.3). However, it does not distinguish between co-processing and WtE. Co-processing in cement kilns is a preferred option between the two for the following reasons:

- Co-processing in cement kilns offers a large-scale solution with material recycling and energy recovery – leaving no residues or ash (approximately 30% residue generated from a WtE plant requires treatment and final disposal).
- Cement kilns already exist and, in most cases, operate round the clock.
- Co-processing has high energy recovery efficiency (compared to 15-30% in a WtE plant).
- GHG emissions will be lower compared to incineration and landfilling.
- Other emissions will normally be unaffected, and most cement plants have emissions control and management systems installed.
- Co-processing is usually cost efficient.

It is important that both pre and co-processing respect the waste hierarchy and therefore do not hamper the efforts towards reduction, reuse, and recycling. Co-processing overlaps with the levels recycle, (energy-) recovery and for selected waste with dispose (GIZ-LafargeHolcim, 2020). Materials which can be recycled in a closed loop (metals, paper, glass, certain plastic types) should not be accepted for pre- and co-processing. In this sense, pre- and co-processing is an integrated waste management solution and not in competition with closed-loop recycling.

This report considers both these technologies as they have relevance for India under different settings. Both use SCF or RDF as a feedstock but work differently and have their respective pros and cons as discussed in the following sections.

1.1 SCF/RDF and its composition

RDF refers to the non-biodegradable and non-recyclable portion of the collected MSW that has high calorific value. RDF may contain a variety of materials and its composition can vary somewhat over time. Hence, different techniques to ensure its homogeneity are required so that it can be used as a substitute to fossil fuels such as coal. The most common way of extracting RDF from MSW is to combine mechanical and biological treatment methods. Such methods include, but are not limited to size screening, coarse shredding, bag splitting, shredding, magnetic separation, refining separation etc. (Broad Group, 2022).

Sometimes a less processed version called Segregated Combustible Fraction (SCF) is used as an alternative or precursor to RDF. Both SCF and RDF are like fuel and can be incinerated to derive embodied energy and material through incineration. The process of using waste as raw material or as a source of energy or both to replace or supplement the natural mineral resources and fossil fuels in industrial processes is known as co-processing.

Composition of RDF varies widely depending on the area (urban/rural), the seasons, the organisation of collection, the food standards of the city, etc. Major components of RDF include plastic, paper, wood, and textiles. The share of these materials in RDF varies from time to time and from sample to sample. As per a study, the estimated composition of RDF is 25% plastic, 21% textiles, 7% paper, 7% cardboard, 15% organics and rest including glass, metal, inerts etc. (Hemidat, et al., 2019). Comparable studies for India are not available.

Plastic waste, an important constituent of RDF, has a very high calorific value i.e., in the range similar or higher than coal and pet coke (approx. 4500-8500 kcal/kg) (Suthar, Lata, & Nagar, 2020), varying with the type of plastic. Given the growing concern around plastic waste management globally, co-processing is one of the best possible solutions for non-recyclable plastic waste.

The composition of the incoming waste stream, collection approach and pre-processing technique deployed are the primary determinants of the quantity and quality of RDF that can be produced per tonne of MSW. In India, the usual yield of RDF from mixed MSW is in the range of 20-30%, although if the waste is properly segregated, a significant higher yield can be achieved (CPHEEO, 2018).

1.2 Landfill mining as a source of SCF/RDF

Landfill mining is a promising approach to address the challenges of landfills and dumpsites. By recovering resources from the waste, the lifespan of the landfill or dumpsite can be prolonged, and land can be reclaimed for other purposes. The composition of the waste in landfills and dumpsites varies with time and operation, but typically contains soil like material, some combustible material, moisture, and other mixed waste.

Landfill mining is not a standardised process, and the approach needs to be tailored to the specific context and available treatment options. In Europe, advanced treatment infrastructure, regulations, and funding schemes have led to the development of advanced landfill mining with the utilisation of multiple waste fractions. Since it is relatively less advanced in India, simpler landfill mining approaches with a focus on combustibles, easily recoverable recyclables, and compost is more common. These typically involve on-site pre-treatment of the waste, manual extraction of recyclables, and mechanical sieving to separate larger fractions from smaller, soil-like materials.

The landfill mining process uses various machineries such as blade drum trommels, refinement trommels, air density separators, and disc screen separators which help in achieving a high degree of segregation, resulting in minimum waste being sent to landfills. The use of bio-culture to stabilise the excavated waste is an eco-friendly method as it promotes the natural decomposition process. The waste is processed and segregated into the four following fractions:

1. Coarse soil and stones which is used for back-filling provided it is not contaminated.
2. Combustible fractions which is sent to the cement plants.
3. Fine soil fraction which can be used for landscaping and afforestation provided it is not contaminated.
4. Recyclable fractions such as glass and iron pieces (1-2%) which are sent to recyclers.

The approach not only reclaims land but also helps in reducing the burden on landfills and promotes sustainable waste management practices.

Annexure 15.1 provides a table with the information on the number of dumpsites, area, and amount of legacy and remediated waste in various states and union territories of India as of September 2021. The data reveals that Maharashtra has the highest number of dumpsites (209) and the largest area (1,805 acres) amongst the listed states. It also has the highest amount of legacy waste (57.9 million tonnes) and waste to be remediated (41.2 million tonnes). Delhi has the second highest amount of legacy waste (28.06 million tonnes) and waste to be remediated (23.76 million tonnes). Karnataka has the highest percentage (97%) of waste yet to be remediated, with 18.00 million tonnes of waste yet to be remediated out of the total waste of 18.48 million tonnes.

Overall, the data suggests that a significant amount of legacy waste remains to be remediated in most states and union territories of India, with an average of 73% of waste yet to be remediated.

Modern society will find no solution to the ecological problem unless it takes a serious look at its lifestyle.

~ Pope John Paul II

Source: SINTEF

2 Policy and Regulatory Provisions Relevant to SCF/RDF Utilisation

Until 2000, there was no specific law for regulating solid waste. The Municipal Solid Waste (Management & Handling) Rules, 2000 were prescribed under the provisions of Environment Protection Act, 1986. They were applicable to every municipal authority responsible for the collection, segregation, storage, transportation, processing, and disposal of municipal solid wastes. It stipulated responsibilities of ULBs, State Governments as well as Central Pollution Control Board and the State Board or the Committees in infrastructure development, setting up landfills and other waste processing and disposal facilities, monitoring and ensuring eco-friendly compliance and submitting Annual Reports (Pandey, 2012) (Vishnoi, 2018).

2.1 Solid waste management rules, 2016

In 2016, the Ministry of Environment, Forest, and Climate Change (MoEF&CC) strengthened the Municipal Solid Wastes (Management and Handling) Rules 2000 and notified the amended Solid Waste Management Rules, 2016 to provide for a more systematic and scientific waste management across urban settlements.

Table 2.1: Responsibilities of various authorities as described under SWM Rules 2016

Authority/Institution	Directives
Ministry of Urban Development (now MoHUA)	Formulate national policy and strategy on solid waste management including policy on waste to energy in consultation with stakeholders within six months from the date of notification of these rules.
Local authorities and village Panchayats	To facilitate construction, operation, and maintenance of solid waste processing facilities with suitable technologies like waste to energy processes including refused derived fuel for combustible fraction of waste or supply as feedstock to solid waste-based power plants or cement kilns.
Industrial units located within 100 km from RDF and WtE plants based on solid waste	All industrial units using fuel and located within 100 km from a solid waste-based RDF plant shall plan within six months from the date of notification of these rules to replace at least 5% of their fuel requirement by RDF so produced.
Ministry of Power to enable through appropriate mechanisms	1. Tariff or charges for the power generated from the waste to energy plants based on solid waste 2. Compulsory purchase power generated from such waste to energy plants by distribution company.
Ministry of New and Renewable Energy Sources enable through appropriate mechanisms	1. Facilitate infrastructure creation for waste to energy plants. 2. Provide appropriate subsidy or incentives for such waste to energy plants.

Source: SWM Rules 2016

The new rules are more comprehensive, and the jurisdiction of the rules has been extended beyond municipal area to cover outgrowths in urban agglomerations, census towns, notified areas and industrial townships etc. It lays down the duties of waste generators and stressed upon source segregation. The responsibilities of various authorities are presented in Table 2.1. The Rules also require all ULBs to establish a proper system of waste management and furnish an annual report to the State Pollution Control Boards (SPCBs)/Pollution Control Committees (PCCs) eventually reaching the Central Pollution Control Board (CPCB).

While SWM Rules 2000 called for collection and disposal i.e., they focused on landfills, the SWM Rules 2016 shifted the attention from collection and disposal to segregation, waste minimisation, establishing holistic waste management systems and keeping landfill as a last resort (Ahuja, 2022). SWM Rules 2016 appear to implicitly promote WtE as technology by prescribing criteria for the same (refer to Table 2.2) as well as by requiring Ministry of New and Renewable Energy (MNRE) to provide subsidy or incentives.

Table 2.2: Criteria for waste to energy process as per the SWM Rules 2016

Criteria for waste to energy process
1. Non-recyclable waste having calorific value of 1500 Kcal/kg or more shall not be disposed off on landfills and shall only be utilised for generating energy either or through refuse derived fuel or by giving away as feed stock for preparing refuse derived fuel.
2. High calorific wastes shall be used for co-processing in cement or thermal power plants.
3. The local body or an operator of facility proposing to set up waste to energy plant of more than 5 TPD processing capacity shall apply to the SPCB or Pollution Control Committee for authorisation.
4. The SPCB or Pollution Control Committee, on receiving such application for setting up waste to energy facility, shall examine the same and grant permission within 60 days.

Source: SWM Rules 2016

2.2 Guidelines on usage of RDF in various industries

Given the increasing quantity of municipal waste combined with a larger fraction of non-recyclables such as multi layered plastic and low utilisation of RDF, an Expert Committee was formed by the Ministry of Housing and Urban Affairs (MoHUA) in 2017.

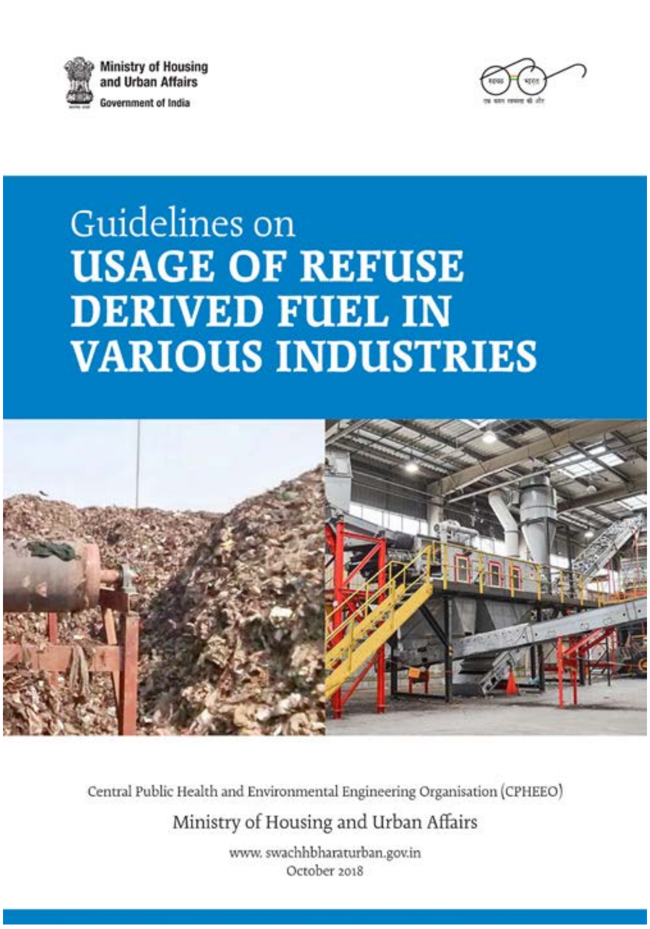
The Committee comprised of representatives from waste management sector as well as various user industries such as cement, power etc. The Committee was mandated to prepare norms and guidelines for use of RDF in various industries in compliance with the SWM Rules, 2016.

To ensure consistency in RDF quality, the Committee also suggested standards for different grades of RDF, including SCF, for utilisation in cement kilns. These are presented in Table 2.3 below. Key recommendations from the Committee are detailed in Table 2.4 below.

The Committee also discussed the potential sustainability of using waste as fuel in cement kilns in India and identified issues and challenges within the supply chain framework that could affect the success of this strategy.

However, the recommendations and standards proposed by the committee are yet to be formally adopted, which partly explains limited use of RDF in the cement industry. Lack of supportive regulatory framework makes it challenging for businesses to invest in the infrastructure and technology necessary to make co-processing a sustainable and viable option.

Figure 2.1: Report of the Expert Committee



Source: CPHEEO

Table 2.3: RDF standards recommended by the Expert Committee

SN	Parameters	SCF	RDF - Grade III	RDF - Grade II	RDF -Grade I
1	Intended Use$	Input material for the WtE plant or RDF pre- processing facility	For co-processing directly or further processing	For direct co-processing in cement kiln	For direct co-processing in cement kiln
2	Size	< 400 mm @	<50 mm or < 20 mm depending upon use in ILC or SLC, respectively		
3	Ash	<20 %#	<15 %	<10 %	<10 %
4	Moisture	<35 %	< 20%	<15 %	<10%
5	Chlorine	< 1.0 % #	< 1.0 %	< 0.7	< 0.5
6	Sulphur	<1.5 % #	<1.5 %		
7	* Net Calorific Value (NCV) – in kcal/kg	> 1500 Kcal/kg net	>3000 Kcal/kg net	>3750 Kcal/kg net	> 4500 Kcal/kg net
8	Any other parameter	Odour control**	Odour control	Odour control	Odour control

Source: Guidelines on Usage of Refuse Derived Fuel in Various Industries (CPHEEO, 2018).

Note:
$ ULB, Cement and other industries to mutually decide which standard of RDF need to be produced.
@ Anything above 400 mm must be mutually agreed between ULB/SCF Supplier and Cement Plants.
# If the blending process is done in cement plants, the deviations in ash, chlorine and sulphur content can be mutually agreed between urban local body /SCF Supplier and cement plants.
* Bandwidth of variations acceptable in NCV can be mutually decided between RDF manufacturer and cement plants- value of NCV is average figure of every individual consignment.
** Since odour is still largely a matter of perception and there is no satisfactory equipment to measure different types of odour, no quantitative figure has been given.

Table 2.4: Recommendations from the RDF Expert Committee on promote RDF usage on an affordable, sustainable, and scalable basis

SN	Recommendations	Responsibility
1	The cement plants located within 400 km from a solid waste-based RDF plant shall make necessary arrangements to utilise RDF to replace at least 15% of its fuel intake within three years from the date of amendment of these rules (equivalent calorific value/TSR) by Municipal Solid Waste based SCF and/or RDF, subject to the availability of RDF (in a phased manner). The transport cost for SCF/RDF up to 100 km from the cement plant shall be borne by cement plant. However, beyond 100 km, cement plant can transport at its own cost or by ULBs as mutually agreed upon by the parties.	MoEF&CC
2	ULB shall manage necessary investment either by themselves or through a private company selected through competitive bidding process on agreed terms and conditions. The Swachh Bharat Mission funds may also be utilised in setting up such plants as VGF/ Grant.	MoHUA through SUDD/ ULBs
3	Model Tender Documents and tripartite agreement between urban local bodies, SCF/ RDF manufacturer, and Cement plants (use Annexure I of the Guidelines for guidance)	ULBs
4	SCF/RDF shall be lifted by Cement Plant /WtE plant on the terms and conditions mutually agreed by the parties on the lines of model agreements. The Cement Plant will pay for SCF/ RDF to ULB at mutually agreed rates based on calorific value of RDF/ SCF and other quality factors on the lines of cost per 1000 kcal, as indicated in the guidelines.	SUDD, ULB and Cement Plants
5	To reduce dependence on cement plants, MoHUA may consider supporting applied research and development for conversion of RDF to liquid/solid/gas fuel or other innovative options with potential replication in the form of 2-3 pilot plants. If successful, this will open additional avenues for RDF utilisation.	MoHUA through SBM or may contact Department of Science and Technology
6	To provide impetus for AFR/RDF standardisation mechanism and its utilisation, collaborative measures on research and development to be initiated by all cement manufacturers, National Council for Cement and Building Materials (NCCBM), Department of Industrial Policy & Promotion (DIPP)	MoCI and MoHIPE (now MoHI)
7	To encourage the use of RDF, the expenses so incurred for transportation of RDF beyond 100 km distance and to be borne by industries or ULBs as mutually agreed, as mentioned under Sl. No. 1 above, may be booked by industries under their Corporate Social Responsibility (CSR) commitment, as per Section 135 of the Companies Act, 2013.	MoHIPE (now MoHI) or DIPP

Source: CPHEEO

2.3 Plastic Waste Management (Amendment) Rules 2022

The PWM Rules (originally notified in 2016) provide measures for managing plastic packaging waste. The rules empowered and enhanced responsibility of the local bodies. Further, responsibilities of both producers and generators (like commercial establishments) were defined as Extended Producer Responsibility (EPR). The Rules also increased the minimum thickness of plastic that can be used to facilitate recycling and collection particularly to promote the use of plastic in avenues such as road construction and waste to energy. Further conditions were laid down for the manufacture, import, sale, and stocking of certain types of plastic.

In 2018, a few amendments including that relating to the definition of multi layered plastic, which is non-recyclable, were introduced. A further amendment in 2021 prohibited the use of certain single use plastics – the prohibition was to come in a year's time- i.e., from 1st July 2022. Further, to prevent littering and reuse of plastic bags, their minimum size was increased from 50 to 75 microns w.e.f. 30th September 2021 and further to 120 microns w.e.f. 31st December 2022. Additional amendments were made to clarify, expand, or strengthen the existing rules.

In February 2022, a major amendment was incorporated relating to EPR to include importers and brand owners, particularly for four categories of plastic which are difficult to recycle. Provision was also made for the Central Pollution Control Board to set up a portal that will be used by producers, importers, and brand owners to file reports required under the rules. A committee has also been set up under the Chairman CPCB to recommend to the Government regarding the effective implementation of the Extended Producer Responsibility.

Further, in a second amendment introduced in July 2022, the concept of bio-degradable plastics was introduced. Certification of the same is to be done initially by CPCB and standards to be specified by Bureau of Indian Standards. It also laid down that environmental compensation shall be levied based on 'polluter pays' principle, on persons not complying with the provisions of these rules. A few other amendments were also made to clarify and amplify the existing rules.

2.4 Tariff for WtE plants

The Central Electricity Regulatory Commission (CERC) notified the Tariff Order for Determination of levellised generic tariff for FY 2022-23 under Regulation 8 of the Central Electricity Regulatory Commission (Terms and Conditions for Tariff determination from Renewable Energy Sources) Regulations, 2020 on November 7, 2022. According to this Order, the Commission shall determine project specific tariff for the MSW, or RDF based power projects based on parameters such as capital cost, plant load factor, auxiliary consumption, station heat rate, calorific value, fuel cost, O&M etc. expenses (CERC, 2022). Since the jurisdiction of CERC relates to inter-state projects and most WtE projects are of relatively smaller size and sell electricity intra-state, tariff of all WtE projects in recent years have been determined by the state regulators. Table 2.5 below presents tariff of some of the recent projects (Refer to Table 15.3 in Annexure for state-wise WtE plants in India).

Table 2.5: Tariff for WtE plants as determined by state Electricity Regulatory Commissions

State	Year	Tariff (INR/kWh)
Karnataka	2022	7.08
Gujarat	2020	7.03 -7.07
Kerala	2021	6.81 (without accelerated depreciation) 6.31 (with accelerated depreciation)
Maharashtra	2021	7.45
Andhra Pradesh	2020	6.165 (for 1st year)-Guntur 6.226 (for 1st year)-Vizag
Haryana	2021	6.84
Tamil Nadu	2019	6.28 (without accelerated depreciation) 5.90 (with accelerated depreciation)

Source: Karnataka (MERCOM, 2021); Maharashtra, Kerala, Tamil Nadu (MERCOM, 2021), Andhra Pradesh (APERC, 2018), Gujarat (TOI, 2020), Haryana (CareRatings, 2020)

2.5 Other schemes and subsidies

Under MNRE's Program on Energy from Urban, Industrial, Agricultural Wastes and Residues and Municipal Solid Waste (2019-20), central financial assistance of INR 50 million per MW was provided for waste to energy projects. However, it is no longer available as per the revised guidelines issued in Nov. 2022.

Swachh Bharat Mission-Urban was launched in 2014 with the objective to ensure 100% scientific Solid Waste Management, among others. In October 2021, SBM(U) 2.0 was launched with the vision to achieve sustainable sanitation and scientific waste processing for 'Garbage Free Cities'. Under SBM (U) 2.0, graded central financial assistance for some specific type of projects is provided. Typical RDF and WtE plants are not included but biogas based plants are eligible to receive graded central financial assistance based on installed capacity and performance.

Figure 2.2: A modern WtE plant in Oslo

Source: SINTEF

3 Options for managing SCF/RDF

This report considers two alternative technologies for recycling and reuse of segregated combustible fraction derived from the municipal solid waste. Given the focus on segregation of waste at source, combined with the development of material recovery facilities, co-processing in cement kilns and waste to energy are considered relevant for the purpose. Further, other options such as pyrolysis or utilisation in thermal power plants have technological limitations, particularly given the characteristic of Indian MSW. Conversion of SCF into RDF further enhances its useability, both in co-processing and waste to energy applications.

Waste to Energy plants present an alternative way of dealing with the SCF. However, WtE recovers energy but is incapable of recovering the material. Further, bottom ash from WtE facilities includes constituents such as heavy metals, toxic compounds, etc., which require further treatment and management. Unless well regulated and managed, the bottom ash can present a significant challenge as evident from the untreated residue dumped in the open at the pit at Tajpur Pahadi by a nearby WtE plant (ThePrint, 2019).

RDF use in cement kilns is a preferred technology compared to WtE incineration because toxic compounds are destroyed more completely at high gas temperatures reaching up to 2000°C combined with a long residence time of 4-5 seconds, effectively replacing the need for very expensive pollution control equipment. Higher temperatures also allow complete incorporation of ashes, including heavy metals, into the clinker material, thereby leading to both energy and material recovery (GGGI, 2022). One significant concern is RDF with high chlorine content, which can negatively impact the cement clinker. However, technical solutions to deal with it exist, though they impose additional cost.

A brief qualitative comparison of the two options is presented below in Table 3.1. It is evident that cement kiln presents several advantages which make it an attractive option to be considered by urban local bodies. However, on ground, WtE appears to be increasingly deployed with over 14 operating plants and 31 under construction (CPCB, 2021; CSE, 2018 and various news articles). A detailed table is included in Annexure B.

Figure 3.1: A MRF in Delhi

Table 3.1: Comparison of co-processing in cement kiln to WtE incineration

Parameters	Cement kilns	Incineration with WtE
Purpose	Industrial production of cement clinker.	Reduce the volume of organic waste, production of electricity in WtE plants.
Temperature ranges	1500-2000 0C. Inherent features, e.g., time, temperatures and oxidising conditions are excellent for waste destruction.	800-1100 0C
Capital Expenditure	Kiln systems are already existing and always operate. The industry bears the investment costs for waste pre- and co-processing.	Expensive to build, operate and maintain. CAPEX is significantly higher (CPHEEO, 2016).
Land requirement	Facilities usually installed inside existing cement plants- no additional land requirement.	For 1000 tpd of mixed waste: 5 ha of land including buffer zone (CPHEEO, 2016)
Operational Expenditure	Usually cost-efficient, biggest driver is transportation cost (distance).	Varies widely. Flue-gas cleaning is often a significant contributor to costs. Receives subsidies from government.
Energy utilization efficiency	Approaches 100%.	Low energy efficiency, range 15%-25% for electricity production (for steam 80%-90%).
Waste type versatility	Certain limitations for example high moisture and Chlorine- pre-treatment of the wastes is usually needed. No limitation on minimum quantity.	More versatile than cement kilns, but wet wastes in rainy season makes efficient operation difficult and will lead to emissions; pre-treatment (especially segregation & drying) will improve efficiency.
Production of residues	No residues.	~ 25%-30% of the incinerated waste ends up as residues and need to be further disposed.
Emissions	Will normally be unaffected if properly operated. Reduces CO2 emissions compared to landfilling and incineration.	Building WtE-incinerators will add several emission points. Incomplete combustion emits a toxic compounds (for example, dioxins and furans), requiring appropriate emissions control systems (CPHEEO, 2016).

Source: Authors

4 SCF/RDF Utilization in Cement Kilns

"

Does what we create justify what we destroy?

– Tony Fry

Given the advantages of coprocessing, this section focuses on utilisation of SCF or RDF for co-processing, mainly in cement industry considering that as the most relevant application. RDF utilisation in other industries such as coal fired power plants or others such as steel that use significant quantities of coal are yet to demonstrate RDF utilisation in significant quantities.

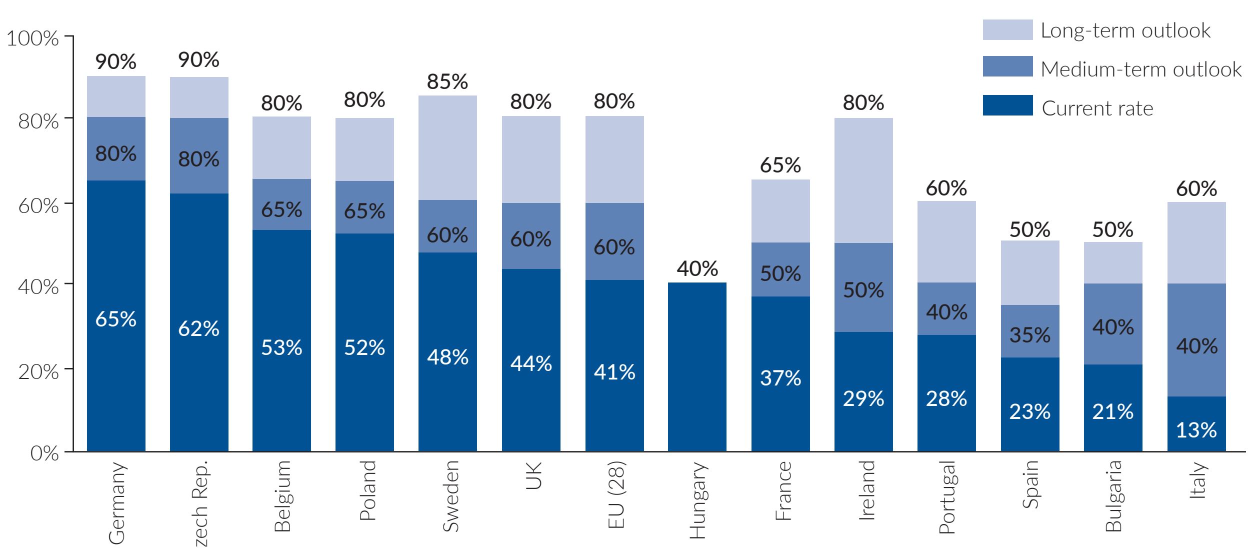
Cement production is an energy-intensive process consuming thermal energy of the order of 3.4 GJ/tonne of clinker produced (Mokhtar & Nasooti, 2020), which accounts for 30% – 35% of total production costs (CMA, 2018). Coal is the predominant fuel used in cement kilns. Cement production consumes approximately 170 kg of coal per tonne of cement (CMA, 2018).

RDF is used as an alternative fuel in the cement industry in many countries (more information in section 4.1) because of various advantages such as sustainable disposal of waste, contribution to preservation of natural resources as well as reduction of global emissions and reduction in manufacturing cost of cement through fuel savings (Cementis, 2022).

4.1 International experience with co-processing SCF/RDF

In the early 2000s, RDF production was most common in member states of the EU (refer to Figure 4.1) that had achieved relatively high levels of recycling and composting, such as Austria, Germany, The Netherlands, and Finland (European Commission, 2003). The high rates of source segregation in these countries allowed for the separation of non-recyclable residues suitable for RDF production. The 'polluter pays' principle was applied in determining responsibilities, and supportive legislative frameworks and government subsidies were laid down to create necessary infrastructure.

Figure 4.1: Current and expected Co-processing rates in 14 European countries



Source: Status and prospects of co-processing of waste in EU cement plants (Ecofys, 2017)

Today, the cement industry in European countries is highly automated, uses alternative fuels and alternative raw materials, and is making significant investments in permits, installations, and abatement technology. Countries with a mature waste management system, smooth permitting procedures, a modern cement industry, and high prices of fossil fuels have higher rates of co-processing. However, the availability of quality waste for the cement industry is perceived as one of the main barriers to increasing co-processing rates. RDFs and SRFs, with biomass content, are considered carbon-neutral and can contribute considerably to the reduction of CO2 emissions. Advanced approaches in Europe have resulted in the production of high-quality RDF with calorific value in the range 3500 – 4300 kcal (Psomopoulos, 2014).

Greece has a high per capita production rate of waste but an underdeveloped waste management system, with most waste being landfilled. In 2012, only 6-7% of waste was co-processed in cement kilns, far lower than the EU average, due to limited availability of suitable materials and uncertain permitting processes. Poland has a ban on landfills and received subsidies from the EU and the national government to install RDF production facilities, resulting in a thermal substitution rate of over 60%.

In Austria, quality criteria for waste fuels burnt in co-incineration plants have been laid down under the "Guideline for Waste Fuels" and the "Waste Incineration Directive," with limits given for heavy metals content (Pomberger & Sarc, 2014). Monitoring at the level of both the supplier and the consumer of RDF is necessary. Austria and Netherlands have achieved TSR exceeding 80%, starting from low levels in 1980s.

The German cement industry is highly energy-efficient and automated, with heavy investments made in co-processing. RDF utilisation is expected to increase as Germany plans to reduce dependence on coal-based thermal power generation. Norway's Norcem cement plants substitute approximately 75% of their coal needs with waste-derived fuel from both hazardous and non-hazardous waste. Norcem Brevik is the first cement plant in the world where the carbon capture and storage (CCS) technology is being tested.

RDF co-processing is gaining momentum in Southeast Asia as well, with countries like Thailand, Vietnam, Lao PDR, and Cambodia adopting RDF co-processing as an alternative to landfills. The potential market for RDF is significant, with countries like Cambodia estimating an annual demand of 420,000 tonnes of RDF for all cement plants, if 20% of the coal is replaced with RDF.

Indonesia has also established targets for thermal substitution of alternative fuels in the cement industry, with a target of 15% by 2025. The country is struggling with overloaded landfills and a low waste recycling rate.

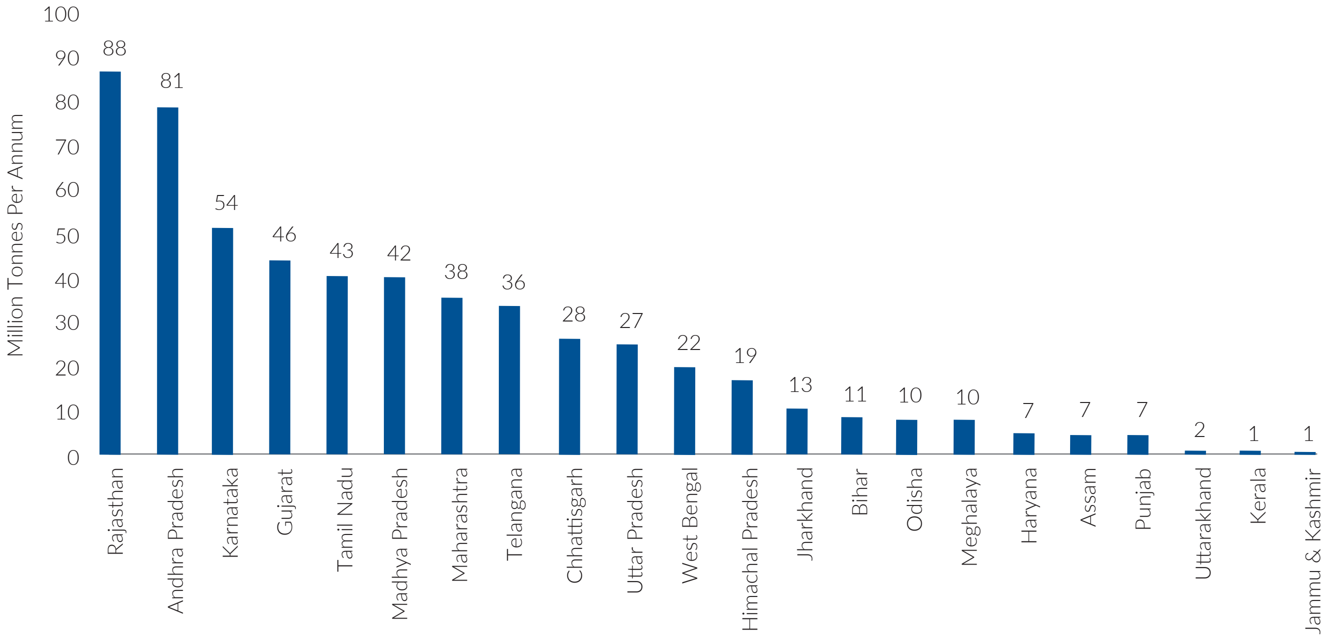
The Chinese government's strategy to integrate waste management with existing industry production has resulted in co-processing becoming an important pillar in the Chinese waste management strategy and in the circular economy. Chinese cement industry co-processes approximately 3.5 million tonnes of raw municipal solid waste (MSW) annually, containing 10-15% plastic, and 2 million tonnes of refuse-derived fuel (RDF), containing 30-40% plastic. Several new and important policies have been issued to promote co-processing. The co-processing of MSW and RDF in cement plants has allowed China's resource efficiency and saving potential to become enormous, with Chinese cement industries investing hundreds of millions of dollars in co-processing technology and know-how.

Overall, evidence points to significant utilisation of RDF in cement kilns starting from Europe but then expanding to other parts of the world. It was initially facilitated by a regulatory intervention i.e., EU Waste Framework Directive but other drivers such as fuel cost optimisation have emerged over time.

4.2 SCF/RDF generation and utilization in India

India is the second largest cement producer in the world with cement manufacturing capacity to reach 500-600 million tonnes a year by 2025 (CMA, 2018). Figure 4.2 shows the cement manufacturing capacity for different states in India which highlights that cement is not concentrated in any single region. Cement plants are quite well-dispersed geographically in the country and are in close reach from most urban locations. There is thus a significant potential for utilising SCF and or RDF for co-processing in cement kilns.

Figure 4.2: State-wise cement manufacturing capacity (Mtpa)



Source: Indian Minerals Yearbook 2020

The Indian cement industry has made significant progress in improving its energy efficiency and productivity through various initiatives. However, the utilisation of alternative fuels and raw materials has remained largely untapped. The Thermal Substitution Rate (TSR) for alternative fuels in the Indian cement industry increased from 0.6% in 2010 to 4-5%, which is still low compared to the EU's average of 40% and Norway's 75%.

Few cement plants in India are, however, operating at up to 20% TSR. The industry has invested significant sums and more than 80 pilot demonstrations or trials have been conducted with different waste streams. Waste regulations broadly support co-processing; emission limit values for co-processing of wastes in cement kilns were notified by MoEF&CC in 2016.

It is estimated that more than 10 million tonnes of RDF are available in 200 km radius of existing cement plants. MoHUA estimates about 4.9 Mtpa of RDF can potentially be available for co-processing in cement kilns (CPHEEO, 2018); pre-supposing that majority RDF will be diverted to WtE plants. Lack of source segregation, poor logistics, and lack of capacity are some of the key reasons for the relatively low quantity and quality of SCF/RDF generated.

However, despite these challenges, there has been an increase in the offtake of SCF and RDF in the cement industry in recent years. This is mainly due to the sustainability imperative and the increase in fossil fuel prices, which have been key drivers in encouraging cement companies to proactively reach out to ULBs (Urban Local Bodies) to negotiate contracts to source SCF and RDF.

SINTEF and CII-GBC gathered information on RDF utilisation from 29 cement plants (refer to table 4.1). During 2021-22, these cement plants co-processed more than 500,000 tonnes of RDF and wastes containing plastic which is estimated to substitute more than 300,000 tonnes of coal.

During the World Environment Day in 2018, the Indian cement industry also took a voluntary target to co-process 12 Mt of plastic waste by 2025. The new PWM Rules (2022) and its EPR mandates open opportunity for cement plants to co-process wastes; earn revenue from EPR certificates.

Table 4.1: RDF utilisation in the Indian cement industry (2021-22)

SN	RDF+/ PW utilisation in 2021-22	RDF used t/y	NCV (Kcal/kg) $	Estimated coal replaced t/y @
1	Ultra Tech Cement Ltd/Vikram Cement Works Khor (M.P.)	1 500	3750	1125
2	UltraTech Cement Limited Reddipalayam	12,200	4600	11,224
3	UltraTech Cement Limited, Narmada cement Jafarabad Works Gujarat	20,000	4500	18,000
4	UltraTech Cement Ltd.- Kovaya	1000	3100	620
5	UltraTech Cement Ltd.- Rajashree	700	4700	658
6	UltraTech Cement Ltd.- Kotputli	100	4500	90
7	UltraTech Cement Ltd.- Raawan	28,700	2100	12,054
8	Aditya Cement Works Chittorgarh	11,700	4500	10,530
9	Birla Corporation	5300	4500	4770
10	ACC Limited- Kymore	20,000	2400	9600
11	ACC Limited- Wadi	66,700	3000	40,020
12	Ambuja Cement Ltd.- Maratha	23,000	2500	11,500
13	Ambuja Cement Ltd.- Ambujanagar	24,500	2500	12,250
14	Ambuja Cement Ltd.- Rabriyawas	15,000	3500	10,500
15	Ambuja Cement Ltd.- Bhatapara	50,000	2200	22,000
16	Dalmia Cement (B) Ltd Dalmiapuram plant	28,000	3000	16,800
17	Dalmia Cement (B) Ltd Ariyalur plant	12,700	3500	8,890
18	Dalmia DSP Limited Kalyanpur, Rohtas, Bihar	500	3000	300
19	Dalmia Cement- Umrangso, Assam	150	3000	90
20	JK Cement Works Muddapur	53,500	2800	29,960
21	JK Cement Works Mangrol	23,200	3200	14,848
22	JK Cement Ltd Nimbahera	75	4500	68
23	JK Lakshmi Cement Ltd.- Sirohi	65,000	3950	51,350
24	My Home- Mellacheruvu	26,200	3000	15,720
25	Orient Cement Ltd. Chittapur	1100	2500	550
26	Orient Cement Ltd. Devapur	1900	3000	1140
27	Chettinad Cement- Ariyalur, TN	150	1000	30
28	Ramco Cement- Alathiyur, TN	4800	1000	960
29	Kesoram Industries	26,700	1500	8010
	Total	**524 375**		**313 657**

Note: $ Weighted average NCV of RDF and plastic wastes used in the Indian cement industry is approximately 3000 kcal/kg

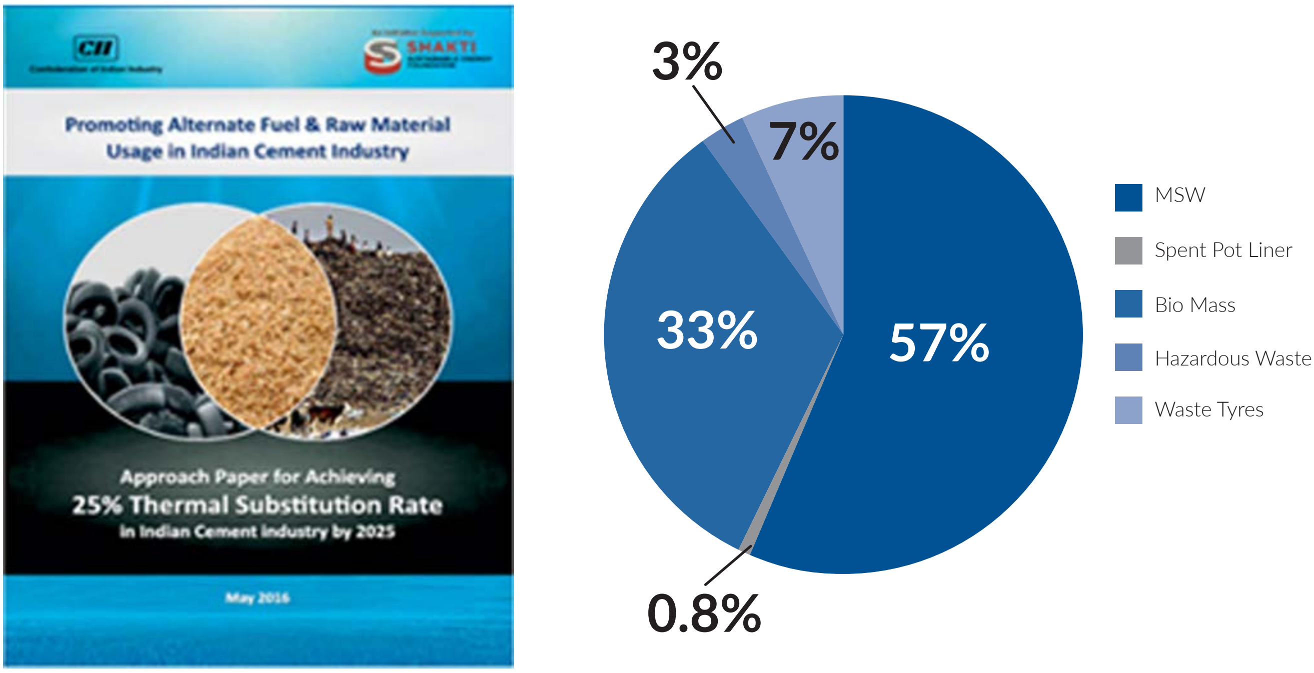
@ For estimating coal quantity replaced by RDF, the NCV of coal is assumed as 5000 kcal/kg.

While these efforts are commendable, it is difficult to conclude that the current efforts are sufficient, given the magnitude of the waste challenge and the need to reduce greenhouse gas emissions from the cement sector. Cement companies have adopted a target to achieve 25% TSR (Thermal Substitution Rate) by 2025. To achieve TSR of 25% by 2025, a large proportion, exceeding 50% of alternative fuels mix will have to be RDF produced from MSW (refer to Figure 4.3). In addition to RDF from fresh waste, combustible fraction of legacy waste will potentially need to be explored.

On the one hand, it is important to ensure that the agreements signed between the cement companies and ULBs are fair and transparent, and that the interests of all parties involved, including the environment and public health, are safeguarded. It is also crucial to ensure that there is a competitive market for SCF and RDF, as this can help to drive down costs and improve quality.

On the other hand, it is important to recognize that ULBs have been under pressure to address the mounting waste challenge, and that cement companies may have provided a valuable solution by using waste as a fuel source in their manufacturing process.

Figure 4.3: Approach for achieving 25% TSR by 2025 in Indian Cement Industry



S. No.	Waste Streams	% share on AF	% share on total thermal energy
1.	MSW	57.07	14.27
2.	Spent Pot Lining	0.81	0.20
3.	Bio Mass	33.97	8.49
4.	Hazardous Waste	3.46	0.87
5.	Tyre Waste	7.33	1.83
	Total		25.66

Source: CII

"

Any waste stream in our society can be turned into a revenue stream. It's turning the lemons in our society into lemonade.

- Billy Parish

Source: RTI

5 Cost Recovery Models

Four cost recovery models are presented in this report. These four models present options for recovering the cost of managing the segregated waste i.e., SCF and or RDF. The following four recovery options are evaluated and presented in Table 5.1.

Table 5.1: Details of the four cost recovery models proposed

Cost recovery model	Description	Infrastructure	Cost recovery method	Benefits	Success factors
1	Deploy cement kiln, recover cost by charging cement consumers	Pre-processing and co-processing established at or near cement plant	Increased cost of cement bag	Straightforward, cost passed on to consumers	Willingness of consumers to pay higher price for cement
2	Deploy cement kiln, recover cost by charging households	Pre-processing and co-processing established within the city; RDF transported to cement plant	Monthly charge to households	Equitable approach, households that generate more waste pay more	Efficient waste collection and payment enforcement
3	Deploy cement kiln, recover cost by charging property owners	Pre-processing and co-processing established within the city; RDF transported to cement plant	Annual surcharge based on area	More equitable and administratively simpler. Spreads cost among all property owners	Accurate assessment of property area and willingness of property owners to pay
4	Deploy waste-to-energy, recover cost through electricity tariff	Waste-to-energy infrastructure established within the city	Increased electricity tariff	Does not require direct payment from households or property owners	Ability to operate plant efficiently and willingness of consumers to pay higher electricity tariff

Source: Authors

It is however important to note the below two points, which are central to this analysis:

a) Recognition of the fact that waste management has a cost i.e., collection, transportation and management on a scientific basis imposes a financial cost. Historically, there has been a reluctance to acknowledge and pay for waste management in monetary terms. This has resulted in a large environmental cost arising from pollution of air, water, and land as well as social cost in form of mortality and morbidity.

b) That the financial cost of managing the waste should be borne by the polluter, following the 'Polluter Pays' Principle which imposes liability on the person polluting the environment. It is instructive to note that the "polluter" i.e., the waste generator is no other than the consumer or more broadly the society. It is also fair to assume that the amount of pollution (waste generated per capita) is directly proportional to income.

The four cost recovery models attempt to identify the financial cost associated with two different technologies (co-processing in a cement plant versus waste to energy) and present different options of recovering the cost. From an economic standpoint, the society is best off when the least cost approach is adopted. However, market inefficiencies, inadequate regulation, and sometimes practical considerations (NIMBY as an example) result in adoption of costlier choices.

Three options for cement kilns have been evaluated due to significantly lower overall cost and technological advantages as discussed previously. It should be noted that these options are not the only ones. For example, in each of Model 1, 2 and 3 it is assumed that the RDF production facility is located within or close to the city. This configuration optimises the transportation cost. However, it is possible to consider an alternative configuration of locating RDF production within or close to the cement facility. This option can be adopted in case where it is relatively easier to locate land within or close to cement facility, relative to the urban locations. The overall results and implications however do not change materially and therefore four options presented here are comprehensive from results perspective.

Figure 5.1: Ghazipur WtE plant in Delhi.

6 Key Assumptions for Cost Recovery Models

We do not inherit the Earth from our ancestors; we borrow it from our children.

– Native American Proverb

This section briefly presents the key assumptions used in all four cost recovery models. Specific assumptions used in each model and the results are presented in the following section. A typical city with MSW generation of 500-1000 tonnes per day is assumed for this analysis. For most of the results, numbers from Agra have been used for illustrative purposes only. To clarify, this analysis is not for the city of Agra per se but some numbers from the city were adopted for illustrative purposes only.

6.1 CAPEX and OPEX

CAPEX and OPEX have been considered separately for RDF production and for co-processing at cement plants. Table 6.1 below presents assumptions for establishing and operating RDF production facility for particle size of 50 mm (or less) with a plant capacity of 12.5 tonnes per hour (tph). CAPEX estimates are based on MoHUA guidelines, 2018 corrected for inflation using Wholesale Price Index. OPEX estimates are also based on MoHUA guidelines, 2018 but were adjusted using Consumer Price Index. Future OPEX increases are assumed to be 5% per annum.

MoHUA guidelines and IFC report (IFC, 2017) were considered for developing CAPEX estimates for co-processing (refer to Table 6.2). The estimates are significantly higher than the MoHUA adopted number but at lower to mid-point of IFC range. Same approach was adopted for OPEX estimates of co-processing as well.

For Waste to Energy facilities, CAPEX is based on estimates provided by various regulatory authorities and industry estimates corrected for inflation using the Wholesale Price Index. OPEX per year is assumed to be 6% of CAPEX with a 5% annual escalation (refer to Table 6.3).

Table 6.1: CAPEX & OPEX of RDF production

		Up to 12.5 tph RDF production capacity		
		Grade III	Grade II	Grade I
CAPEX (Total)	Million INR	176	179	186
OPEX (Year 1)	Million INR	34.7	35.5	37.2

Table 6.2: CAPEX & OPEX of RDF co-processing at cement plant

		Up to 12.5 tph RDF co-processing capacity		
		Grade III	Grade II	Grade I
CAPEX (Total)	Million INR	98	92	80
OPEX (Year 1)	Million INR	31.2	30.5	29.7

Table 6.3: CAPEX & OPEX of WtE incineration plant

		6 MW electricity production capacity
CAPEX (Total)	Million INR	1 320
OPEX (Year 1)	Million INR	793

Source: Authors

6.2 Financing cost

Debt and Equity are two common sources of financing for companies. Debt financing involves borrowing money from lenders, while equity financing involves selling ownership stakes in the company to investors (refer to Table 6.4). It is important to note that the actual cost of debt, cost of equity, and working capital cost may vary depending on various factors such as market conditions, credit rating of the borrower (assumed in this case as CRISIL A or above), industry sector, etc. Therefore, it is important to conduct a thorough analysis and research before arriving at the actual costs.

Table 6.4: Assumptions for estimating financial costs

Category	Rate	Explanation
Cost of debt	11.5%	This means that if a company borrows money through debt financing, it will have to pay an annual interest rate of 11.5% on the amount borrowed. This is calculated from Marginal Cost of Funds-based Lending Rate (MCLR) for the last 6 months, plus a margin of 3.33% for debt financing. MCLR is the minimum interest rate that a bank can lend at, and it is calculated based on the bank's cost of funds. The margin of 3.33% is the additional interest rate that a lender will charge above the MCLR. This means that if the MCLR is 8.17%, then the total interest rate for the loan would be 11.5% (8.17% + 3.33%).
Cost of equity	16%	The equity risk premium is assumed to be 4.5%. A risk premium is the additional return that investors require to compensate them for the risk of investing in a particular asset. In this case, the risk premium of 4.5% and cost of debt of 11.5%, means that investors will expect a return of 16% on their investment in equity.
Debt: Equity ratio	75:25	This is a measure of a company's financial leverage, which is the amount of debt relative to equity that it has. A higher debt to equity ratio means that a company has more debt relative to equity. In this case, the ratio of 75:25 means that the company has 75% of its financing from debt and 25% from equity.
Working capital	14%	Working capital is the amount of money a company has available for its day-to-day operations. It is assumed that the cost of working capital is 14%.

Source: Authors

6.3 Transport cost and distance

For transporting SCF or RDF, analysis done by CPHEEO is adopted as the starting point. Accordingly, the transport cost varies 4 INR/tonne/km and for a transport distance of around 300 kms and reduce to 3 INR/tonne/km for a distance up 600 km and above. The cost of transportation decreases with increase in distance (MoHUA, 2018) (refer to Table 6.5). This is the case even for coal transportation costs by Indian Railways (refer to Figure 6.1).

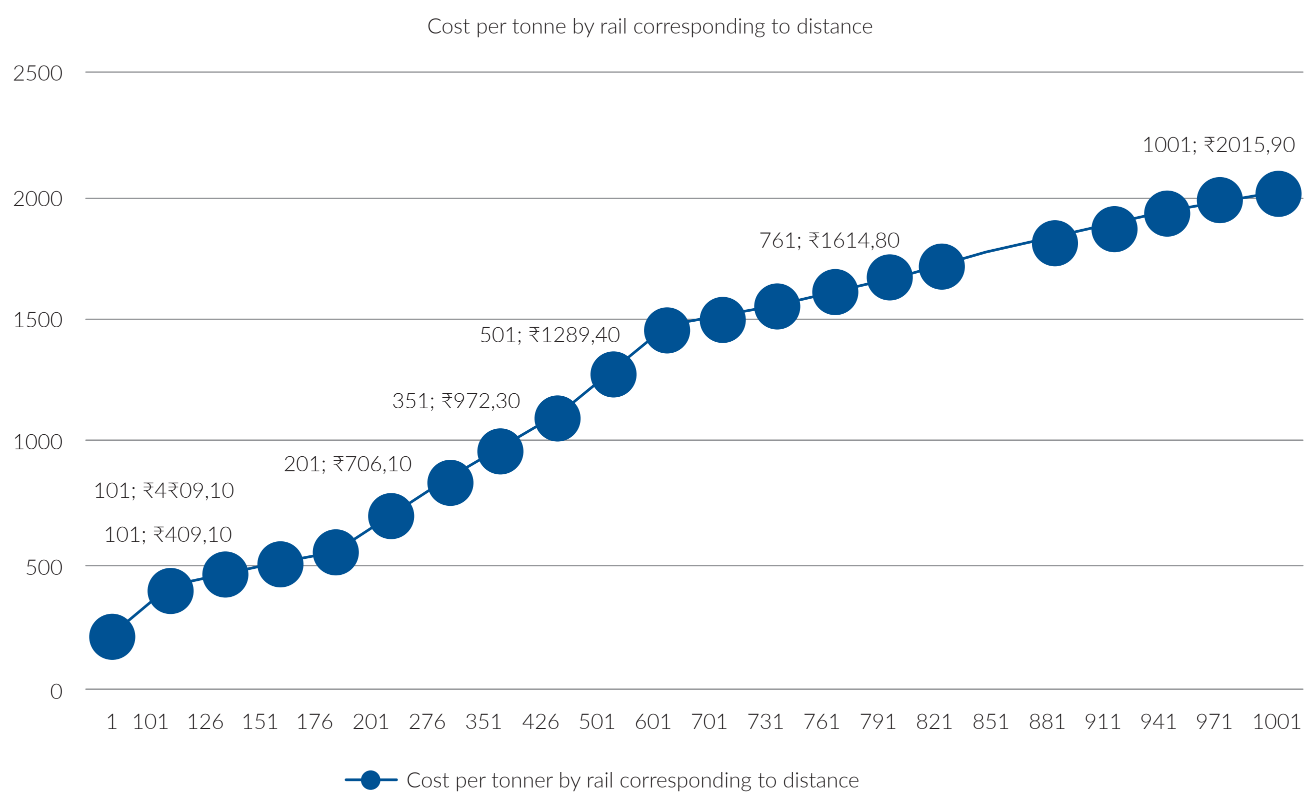
However, this analysis uses higher estimate for transport cost, given the increase in crude oil prices during 2022. As evident from the table below, a significantly higher estimate for transport cost is assumed. However, a conservative approach of adopting maximum possible increase has been adopted to test the robustness of the results. Transport distance is assumed to be 300 KMs in all cases.

Table 6.5: Transportation costs for SCF/RDF by road

Transportation Distance (km)	Transportation Cost Range as per CPHEEO (INR/km/tonne)	Transportation Cost Assumed in this report (INR/km/tonne)
0-30	10 to 12	18.5
31-120	7 to 10	15.4
121-250	4 to 7	10.8
251-600	3 to 4	6.2
601-1300	2.8 to 3.2	4.9

Source: Authors

Figure 6.1: Transportation costs for Coal by Rail up to 1000 km- applied by the Indian Railways



"Refuse what you do not need; reduce what you do need; reuse what you consume; recycle what you cannot refuse, reduce, or reuse; and rot (compost) the rest."

- Bea Johson

Source: SINTEF

7 Results of the Cost Recovery Models

The chapter discusses the results of the four cost recovery models for a specific case, along with the assumptions made for that case. Although similar results were obtained for other cases, only one case is presented here for brevity purposes, to highlight the mechanism and associated costs. The following section will provide a comparative analysis.

7.1 Cost recovery model 1: recover cost by charging cement consumers

In the proposed Model 1, the RDF is produced close to the city and is pre-processed and co-processed in the cement kiln. The cost associated with RDF production and processing are passed to cement consumers through cement prices. Cement consumers, directly or indirectly, are also waste producers. It is also reasonable to assume that larger cement consumers typically generate larger quantity of waste. Results are presented for Grade III RDF with particle size 50 mm and below (refer to table 7.1).

Table 7.1: Specific assumptions and results for Cost Recovery Model 1

Specific assumptions for Cost Recovery Model 1	
CAPEX total and annualized (INR million)	Total = 176, Annualized = 32
Depreciation	90% in 10 years, salvage value = 10%
Operation duration	300 days, 16 hrs/day
RDF quantity (tonnes)	51,000
RDF grade and size (mm)	Grade III, <50 mm
OPEX Year 1 (INR million)	34.7
OPEX escalation	5% per annum
RDF transport distance (km)	300
RDF transport cost Year 1 (INR million)	94.2
CAPEX coprocessing total and annualized (INR million)	Total =97, Annualized = 17
OPEX RDF coprocessing Year 1 (INR million)	31.3
Coal displaced (tonnes)	26,043
Coal savings Year 1 (INR million)	142
Net annualized cost (INR million)	67.5
Results of the Cost Recovery Model 1	
Net annualized cost (INR million)	67.5
Net annualized cost per ton of RDF (INR/tonne)	1324
Increase in Price of 50 kg Bag (INR/ cement bag)	2.50
Increase in Price of 50 kg Bag (%)	0.75%

Source: Authors

The increase in cost of a cement bag required to recover the net annualized cost of INR 67.5 million is only INR 2.5 per bag of cement produced, which represents a modest increase of 0.75% on the average price of a 50-kg cement bag of INR 330. This calculation was done for a cement plant producing one million tonnes of clinker and 1.35 million tonnes of cement (27 million cement bags of 50 kg each).

It is worth noting that these results are conservative and do not consider potential (increased) savings from coal substitution, which can be significant, especially given the recent increase in coal prices. For instance, the calculations consider the coal price to be approximately INR 1 per 1000 kcal, whereas at the height of the pandemic, the coal prices were reported to be more than INR 3 per 1000 kcal (FinancialExpress, 2022). The latest price for imported coal has normalized to INR 2 per 1000 kcal (GlobalCement, 2023).

Overall, the increase in cost of a cement bag required to recover the net annualized cost of INR 67.5 million is relatively modest, and potential savings from coal substitution may make the project even more economically viable.

7.2 Cost recovery model 2: recover cost by charging households

In the proposed Model 2, the RDF produced close to the city and is pre-processed and co-processed in the cement kiln. The cost associated with RDF production and processing are passed to all households in the city in form of a waste management charge, since they are a primary source for generation of municipal solid waste. All other assumptions are same as in Model 1 and reproduced for reference in Table 7.2.0

Table 7.2: Specific assumptions and results for Cost Recovery Model 2

Specific assumptions for Cost Recovery Model 2	
CAPEX total and annualized (INR million)	Total = 176, Annualized = 32
Depreciation	90% in 10 years, salvage value = 10%
Operation duration	300 days, 16 hrs/day
RDF quantity (tonnes)	51,000
RDF grade and size	Grade III, <50 mm
OPEX Year 1 (INR mn)	34.7
OPEX escalation	5% per annum
RDF transport distance (km)	300
RDF transport cost Year 1 (INR million)	94.2
CAPEX coprocessing total and annualized (INR million)	Total =97, Annualized = 17
OPEX RDF coprocessing Year 1 (INR million)	31.3
Coal displaced (tonnes)	26,043
Coal savings Year 1 (INR million)	142
Net annualized cost (INR million)	67.5
Results of the Cost Recovery Model 2	
Net annualized cost (INR million)	67.5
Net annualized cost per ton of RDF (INR/tonne)	1,324
Number of households	315,000
Waste Management Charge (INR/month)	18

Source: Authors

The estimated average cost to be charged to households is INR 18 per month or INR 220 per annum, based on a population of approximately 1.6 million with 315,000 households and an average household size of five. However, it is recognized that not all households may be able to afford this cost.

To address this concern, selective implementation may be considered based on income or location. For instance, the charge could be applied only to households above a certain income threshold or those living in certain areas of the city. Excluding some households, say 50%, will double the monthly cost for remaining households to approximately INR 35-40 per month, which is still considered relatively modest compared to other services such as monthly rental on a cellular service or cable television.

Overall, implementing this approach may require some adjustments to ensure that it is affordable for all households while still recovering the cost of the RDF waste management approach. Selective implementation could be one way to achieve this balance.

7.3 Cost recovery model 3: recover cost by charging property owners

In the proposed Model 3, the RDF produced close to the city and is pre-processed and co-processed in the cement kiln. The cost associated with RDF production and processing are passed to all property owners in the city by increasing the property tax. Since the amount of waste generated is typically proportional to the size of the property, this approach is more progressive than a flat charge for all households. All other assumptions are same as in Model 1 and reproduced for reference in Table 7.3.

Based on the results of Cost Recovery Model 3, the incremental cost of implementing the RDF approach is INR 4 per thousand square feet per month or less than INR 50 per annum. This incremental cost will be charged to all property owners in the city in the form of a Property Surcharge to recover the net annualized cost of INR 67.5 million or approximately INR 1,325 per ton of RDF. The total built-up area of the city is approximately 1,276 million square feet, comprising residential, commercial, and industrial establishments.

Table 7.3: Specific assumptions and results for Cost Recovery Model 3

Specific assumptions for Cost Recovery Model 3	
CAPEX total and annualized (INR million)	Total = 176, Annualized = 32
Depreciation	90% in 10 years, salvage value = 10%
Operation duration	300 days, 16 hrs/day
RDF quantity (tonnes)	51,000
RDF grade and size	Grade III, <50 mm
OPEX Year 1 (INR million)	34.7
OPEX escalation	5% per annum
RDF transport distance (km)	300
RDF transport cost Year 1 (INR million)	94.2
CAPEX coprocessing total and annualized (INR million)	Total =97, Annualized = 17
OPEX RDF coprocessing Year 1 (INR million)	31.3
Coal displaced (tonnes)	26,043
Coal savings Year 1 (INR million)	142
Net annualized cost (INR million)	67.5
Results of the Cost Recovery Model 3	
Net annualized cost (INR mn)	67.5
Net annualized cost per ton of RDF (INR/tonne)	1,324
Total Area (million sq.ft.)	1,276
Property Surcharge (INR/thousand sq.ft./annum)	48

Source: Authors

This approach is progressive as smaller property owners, who typically generate lower quantity of waste will be charged less. It is also administrative simple since property tax and surcharge can be paid once a year. However, if smaller property owners are to be entirely exempted, the surcharge on remaining property owners will need to proportionately increase. Overall, the results Model 3 suggest that the incremental cost of implementing the RDF approach is relatively modest and should be feasible for property owners to bear.

7.4 Cost recovery model 4: recover cost through electricity tariff

The proposed Model 4 involves using the municipal solid waste (MSW) generated in the city to produce solid recovered fuel (SRF) or refuse-derived fuel (RDF) through a processing facility. The RDF is then transported to a waste-to-energy (WtE) facility located within or near the city, where it is incinerated to generate electricity (refer to Table 7.4).

The cost of RDF production and processing is passed on to the electricity consumers in the city in proportion to the energy consumed. This means that consumers who use more electricity will pay a higher proportion of the RDF processing cost, while those who use less will pay less. Since the electricity distribution companies often have larger jurisdictions, the cost will be spread over a larger base of consumers. However, in this report, the electricity sales from the Agra city are used for cost recovery modelling purposes. This ensures consistency of results across various models and provides a standardized approach for comparison. It also allows for a more detailed analysis of the impact of RDF processing costs on electricity prices in a specific city.

Table 7.4: Specific assumptions and results for Cost Recovery Model 4

Specific assumptions for Cost Recovery Model 4	
CAPEX total and annualized (INR million)	Total = 1320, Annualized = 184
Depreciation	90% in 20 years, salvage value = 10%
Plant Load Factor	75%
OPEX Year 1 (INR million)	79.3
OPEX escalation	5% per annum
Total annualized cost (INR million)	263.3
Results of the Cost Recovery Model 4	
Total annualized cost (INR million)	263.3
Net annualized cost per ton of RDF (INR/tonne)	5,162
Total Electricity Consumption (GWh) for major categories	2,543
Increase in electricity tariff (INR/per kWh)	0.11

Source: Authors

Based on the results of the Cost Recovery Model 4, it is estimated that a modest increase of INR 0.11 per kWh of electricity consumption is required to recover the total annualized cost of INR 263.3 million. This increase in electricity tariff is required to realize the cost of approximately INR 5,200 per ton of RDF.

The total electricity consumption for major categories, including residential, industrial, commercial, and others such as public institutions, is approximately 2,543 GWh. The increase in electricity tariff will be proportionate to the electricity consumption of each category. This approach is progressive, as smaller waste generators tend to have lower electricity consumption.

However, if a proportion of consumption, say up to the lowest slab of 100 kWh per month, is to be entirely exempted from the increased tariff, the increase on remaining consumption will need to be proportionately higher to recover the total annualized cost.

Overall, the Model 4 suggests that a modest increase in electricity tariff is sufficient to recover the cost of RDF production. The specific details of how this increase will be implemented and distributed among different categories of consumers will depend on circumstances and state regulations.

Figure 7.1: Transportation of SCF

Source: SINTEF

"

I wrapped my Christmas presents early this year, but I used the wrong paper. See, the paper I used said 'Happy Birthday' on it. I didn't want to waste it so I just wrote 'Jesus' on it.

- Demetri Martin

Source: RTI

8 Comparative Analysis and Inferences

The report considers two alternative technologies for managing the segregated combustible fraction of municipal solid waste and recommends that the 'Polluter Pays' principle should be adopted for the cost of managing the waste.

To implement the 'Polluter Pays' Principle, the report evaluates four different cost recovery options, including a direct charge for waste management. These options provide alternative mechanisms that can be adopted depending on the context. By evaluating different cost recovery business models, the report aims to help decision-makers determine the most appropriate way to finance waste management in their local context (refer to Table 8.1). Implementing them will enable raising financing required for implementing these projects either by urban local bodies or private sector in PPP mode. It is also possible to access pools of international capital such as the Global Climate Fund etc., given that co-processing provides co-benefits of mitigation and adaptation.

Table 8.1: Comparative analysis of results of the four cost recovery models

Parameters	Model 1: Recovery through cement price increase	Model 2: Recovery through waste management charge	Model 3: Recovery through property surcharge	Model 4: Recovery through electricity tariff
Total Annualized Cost (INR million)	67.5	67.5	67.5	263.3
Annualized Cost per tonne of RDF produced	1324	1324	1324	5162
Cost to Customers	INR 2.5 / bag	INR 18 /month/ household	INR 48 / 000sq.ft/ annum	INR 0.11 / kWh
Mechanism for recovering cost	Market prices	Urban Local Bodies	Urban Local Bodies	Electricity distribution companies & State Electricity Regulators

Source: Authors

From the comparative analysis of the four cost recovery models, the following conclusions can be made:

- The cost to customers on a per unit basis for scientifically managing waste is relatively small, regardless of the technology used.
- Waste to Energy is significantly costlier than co-processing segregated waste in a cement kiln, due to the higher investment required and the savings in fuel costs associated with co-processing.
- Depending on context, passing the cost to customers will require political will, regulatory and administrative action.
- Urban Local Bodies are responsible for waste management and will need to take action, particularly for Options 2 and 3, which are direct options where costs are recovered directly from households and waste generators.
- For Options 1 and 4, which are indirect options and costs are recovered indirectly from households and waste generators will require action from other stakeholders.
- Cement companies would need to raise prices for their customers to adopt Option 1, but this may be feasible if all companies increase prices or if some companies can offset the

increase with other efficiencies. Implementing recommendation of the MoHUA Expert Committee can enable uniformity and co-ordination across the industry.

- Option 4 requires electricity distribution companies and state regulators to pass costs through the electricity tariff. Even though the overall cost is significantly higher relative to co-processing, the cost on a per unit basis is relatively low and maybe acceptable if tangible benefits are communicated and demonstrated to citizens.

Figure 8.1: Baled SCF

Source: SINTEF

9 Material Recovery Facility

> *I have found no greater satisfaction than achieving success through honest dealing and strict adherence to the view that, for you to gain, those you deal with should gain as well.*
>
> *- Alan Greenspan*

Production of SCF or RDF in significant quantities will require establishment of Material Recovery Facilities in cities. This is an efficient route to co-processing since it minimizes transport quantity and cost.

As per the SWM Rules, 2016 "Materials Recovery Facility" (MRF) means a facility where non-compostable solid waste can be temporarily stored by the local body or any person or agency authorized by any of them to facilitate segregation, sorting and recovery of recyclables from various components of waste by authorized informal sector of waste pickers, informal recyclers or any other work force engaged by the local body for the purpose before the waste is delivered or taken up for its processing or disposal. As per the Rules, it is the duty and responsibility of the ULB to setup MRFs or secondary storage facilities with sufficient space (MoEFCC, 2016).

The main function of the MRF is to maximize the quantity of recyclables processed, while segregating materials that will generate the highest possible revenues from the recycling market. MRF also helps in segregating combustible fraction (RDF), non-recyclables and inert from the dry waste stream (CPHEEO, 2020). MRFs can thus act as crucial generation points for RDF. Segregation helps in separating out the high calorific waste from the rest and primary processing like drying and shredding increases the calorific value of this dry non-recyclable combustible waste. This can then be supplied to cement industries for co-processing. This can save industries from setting up their own plant for pre-processing of RDF.

MRFs can be of two different types based on the kind of waste processed. First, it can be a mixed facility (processing mixed waste consisting of both biodegradable and non-biodegradable material) or a dry facility (processing only source segregated dry waste). Based on the level of automation, MRFs can also be categorized as manual, semi-automated and fully automated. A typical MRF centre consists of sorting and screening processes, ferrous and non-ferrous metal separation, size and moisture reduction, segregation of non-recyclables and combustibles, and baling.

MRFs offer several advantages and environmental benefits. These centres act as crucial intermediary step that segregates and processes waste to provide valuables. They act as an important cog in the circularity wheel and some key benefits are listed below:

- Maximises the quantity of recyclables from waste.
- Brings back valuable scarce resources into the economic circle
- Reduces carbon, environmental and material footprint.
- Reduces burden of managing untreated waste.
- Generates livelihood opportunities in local economy.

As per SBM-Urban database, a total of 4956 MRF centers exist in the country. Tamil Nadu, Uttar

Pradesh, and Maharashtra are leading states that have maximum number of MRFs. On the other hand, West Bengal and Delhi have very few centers, even though both generate significant quantity of waste (CPCB, 2021). Other big states that have shown limited progress are Bihar and Chhattisgarh, (SBM (Urban), 2023). State by state details of MRF in the country are included in Annexure 15.2.

As per MoHUA, the cost of establishing and operating MRF varies depending on the type of facility established. For a small town with a population less than 0.1 million, a manual facility with CAPEX less than ₹10.0 million may suffice. For mid-sized towns with population between 0.5-1.0 million, semi-automate facility with CAPEX of ₹60 million may be needed. Large metros with population exceeding 1.0 million will likely need automated facility with CAPEX in ₹ 200-300 million depending on size and specifications. OPEX per annum varies between 5%-10% of CAPEX for mid-sized and large facilities. For manual facilities, OPEX maybe considerably higher. These estimates are based on CPHEEO's Advisory on Material Recovery Facility (MRF) for Municipal Solid Waste (CPHEEO, 2020)

Figure 9.1: Material Recovery Facility in Delhi

Source: RTI

10 Economics of Managing Dumpsites

"

There is no such thing as 'away.' When we throw anything away, it must go somewhere

- Annie Leonard

In addition to utilization of fresh waste stream, biomining of existing dump sites is a potential alternative source of SCF or RDF. As already detailed, there are over two thousand legacy dumpsites across the country. Efforts are being made to remediate them given the environmental and public health risks. From a society's perspective, economic benefits exceed the financial cost associated with mining, even if the recovery of useable materials is low.

According to CSE, the average cost of processing one tonne of legacy waste is between Rs 750 to 900 (CSE, 2020), and it includes the cost of manpower and moving the screened fractions off-site, which varies from city to city. The capital cost of the mobile equipment with a capacity of 700 tonnes per day is estimated to be around Rs 10 crore (CSE, 2020).

The operational expenditure of a biomining project depends on the size of the dumpsite and the quantity of waste excavated and processed. Major players in biomining use PLA-based (programmable logic array) systems to regulate the flow of stabilized waste from one trommel to another. The cost of transporting the combustible fractions depends on the distance of the cement industries from the biomining site.

It is essential to note that the cost of a biomining project may vary depending on various factors such as the type of waste, its composition, location, and the size of the dumpsite (refer to Table 10.1). Therefore, it is necessary to conduct a detailed feasibility study before undertaking a biomining project to determine its actual operational expenditure.

Figure 10.1: Dumpsite Mining in Delhi

Source: RTI

Table 10.1: Treatment and disposal costs- case studies from Indian dumpsites

City	Dumpsite	Total dumpsite area (Acres)	Accumulated waste quantity (Mt)	Total project cost (INR millions)	Legacy waste treatment & disposal cost (INE/t)
Agra	Kuberpur dumpsite	42	0.94	304.5	324
Bhopal	Bhanpur Khanti	39	1.1	420	378
Chandigarh	Daddumajra	20	0.5	330	660
Delhi	Ghazipur	70	14		306
Indore	Devguradiya dumpsite	100	1.5	540	450
Nagpur	Bhandewadi- site A	25	1	788	788
Nagpur	Bhandewadi- site B	29	1.3-1.4	609	1015
Nashik	Khatprakalp	6	0.19	34	180
Noida	Sector 54	4	0.1	119.3	1193
Noida	Sector 145	20	0.5	493	986
Surat	Khajod	151	2.5		166
Tiruchurapalli	Ariyamanglam	47.5	0.5	520	684
Tirupati	Ramapuram	25.26	0.2	186.4	911
Vadodara	Altadara	19	0.37	332.6	887
Vadodara	Makarpura	12	0.4	336.8	882
Vijaywada	Ajith Singh Nagar	44.31	0.3	257	842

Data from (Singh, 2022)and (MoHUA, 2022)

11 Adopting Public Private Partnerships for Waste Management

"

If working apart we're a force powerful enough to destabilise our planet, surely working together we are powerful enough to save it

- Sir David Attenborough

Solid waste management is the responsibility of Urban Local Bodies with state level legislations and rules that govern their functioning. However, the performance of urban local bodies on collection and management of waste has been sub-optimal, as noted by several experts such as Dey (Dey, 2018). This has led to an increasing trend towards public private partnerships (PPPs) for waste collection and management.

Under PPPs, a private entity is given the right (concession) to perform specific activities related to waste management for a defined term. PPPs can be successful because private entities have access to capital and are driven by commercial motivation, which can lead to more efficient waste management practices. In India, while PPPs have been implemented successfully in some cities, there have also been challenges in managing these contracts.

The services provided under PPP include door-to-door collection, street sweeping, storage and transportation, treatment and disposal, primary collection, and integrated MSWM. The cities that have implemented these services under PPP are Bangalore, Ahmadabad, Nagpur, Jaipur, North Dumdum, New Barrackpore (West Bengal), Gandhinagar, Delhi, Surat, Hyderabad, Mumbai, Coimbatore, Kolkata, and Chennai. The details of the activities delegated through PPP vary from city to city (ICRA Management Consulting Services Limited INDIA).

The success of PPPs in waste management depends on developing contracts and structures that provide flexibility to both parties. Instead of rigid contracts, it may be relevant to include built-in provisions that allow for transparent reviews and mid-term corrections. This can help to ensure that the private sector partner is able to adapt to unanticipated developments, and that changes to the contract are made in a way that benefits both parties. It is important to note that revisions to the contract should not result in additional profit for the private sector partner but should instead revert to the original economic conditions.

Such an approach is consistent with the recommendations of the Kelkar Committee on PPPs (DEA, 2015). The following recommendations from the Kelkar Committee on PPPs provide valuable insights into how the waste management sector can be effectively managed through public-private partnerships (PPPs).

- **Change in mindset:** PPPs involve long-term contracts that inherently involve uncertainties. Public authorities need to accept this fact and develop mechanisms to deal with these uncertainties. This requires a change in mindset towards a more collaborative approach with private partners, which will help to mitigate risks and improve project outcomes.

- **Specific model concession agreements:** The waste management sector requires a sector-specific model concession agreement to ensure that individual project managers are not burdened with the task of developing one. The model concession agreement should have provisions for modification to suit a particular project, as each project has unique requirements.
- **Equitable risk-sharing arrangements:** Equitable risk-sharing arrangements should be developed to allocate risks to the party best suited to manage them. ULBs will have to sustain a higher level of risk initially, and contracts can be modified progressively as the sector matures and data from initial projects is available transparently to all parties. A minimum monthly amount should be paid to the private partner to ensure continuity of service, and higher payments should be based on verifiable performance matrices to incentivize high-quality service delivery.
- **Amendment to the Prevention of Corruption Act:** The amendment to the Prevention of Corruption Act in 2018, accepting that not all errors are mala fide, will encourage honest public servants to take decisions without the fear of criminal action if some errors are detected later.

Implementing these recommendations will require a collaborative effort from public authorities, private partners, and other stakeholders involved in the waste management sector. However, if these recommendations are effectively implemented, they will go a long way in improving the efficiency and effectiveness of waste management services delivered through PPPs.

12 International Climate Financing for SWM

> "
>
> ***An investment isn't an investment if it destroys our planet***
>
> *- Greenpeace*

Given the interlinkages between waste management (or lack thereof) and climate impacts, there is a broad acceptance and acknowledgement of need to enhance capital for the sector. Many international development banks and agencies provide financial assistance in various forms. ULBs therefore have an opportunity to access international funding for solid waste management activities, including for co-processing and WtE.

In this section, a brief introduction to some of the international sources is provided for sharing information with stakeholders. International funds, such as the Green Climate Fund (GCF), Global Environment Fund (GEF) and Adaptation Fund, provide an important additional source of funding. By their structure, these funds supplement limited budgetary resources of government agencies and enable attracting larger pools of private financing. Therefore, they can play an important role in the overall financing strategy.

This report focuses on some of the larger funds, such as GCF, which have significant potential in the Indian context. Some of the key features, approaches used, and examples of projects financed are detailed to illustrate the potential. However, the process requirements and timelines for accessing these funds requires significant initial investment from the concerned stakeholders.

Two aspects require mention. First, there is a need to significantly strengthen institutional capacity to prepare and implement a pipeline of climate projects. In this regard India is well placed with programs such as the Swachh Bharat Mission, Housing Program etc. which provide a platform to develop a pipeline of city and state level projects. Second, governance and public finance management needs to be strengthened since these funds can only be accessed through accredited agencies. Given India's robust systems, multiple agencies such as the National Bank for Agriculture and Rural Development (NABARD) or the Small Industries Development Bank of India (SIDBI) etc., have been accredited.

While this initial investment can sometimes be intense, these efforts can unlock significant level of cheaper international climate funds. Further, strengthening of institutional capacity is beneficial otherwise to maximize impact of the investments. Likewise, enhancing PFM etc. can provide broader macroeconomic advantage and potentially reduce cost of funds. Beyond specialized climate funds, institutions such as the World Bank and ADB also provide capital and technical assistance through central government route.

Green Climate Fund (GCF): GCF is a dedicated climate fund established in 2009-10 with the purpose of supporting developing countries raise and realize their Nationally Determined Contributions (NDC) ambitions towards low-emissions, climate-resilient pathways. GCF focuses on investments in four key areas – built environment; energy & industry; human security, livelihoods and wellbeing; and land-use, forests and ecosystems.

GCF support includes following types of interventions:

- Transformational planning and programming: by promoting integrated strategies, planning and policymaking to maximize the co-benefits between mitigation, adaptation and sustainable development.
- Catalysing climate innovation: by investing in new technologies, business models, and practices to establish a proof of concept.
- De-risking investment to mobilize finance at scale: by using scarce public resources to improve the risk-reward profile of low emission climate resilient investment and crowd-in private finance.
- Mainstreaming climate risks and opportunities into investment decision-making to align finance with sustainable development.

GCF finances both mitigation and adaptation actions. GCF adopts a country-driven approach, to enable local ownership of financing decisions to enable countries to achieve their respective NDC ambitions. GCF also supports capacity-building through its Readiness Programme, available to all developing countries. To date, GCF has committed a total investment of USD 12 billion towards climate action and has financed about 216 projects across the globe.

GCF can provide a flexible combination of grant, concessional debt, guarantees or equity instruments to leverage blended finance and crowd-in private investment. Typically, GCF operates through a network of over 200 Accredited Entities and delivery partners who work directly with countries for project design and implementation. In India, GCF has four accredited entities i.e., NABARD, SIDBI, IDFC Bank and IEISL.

Specifically for urban SWM, GCF identifies 'Circular Urban Economy' as one of the four themes in the urban sector, under the mitigation pillar 'Buildings, Cities, Industries, and Appliances'. As interventions, GCF supports two areas of the SWM supply chain i.e., (i) waste collection, distribution of recycled materials, and final disposal, and (ii) manufacture and distribution of products made from recycled materials. For waste collection, conventional models like revenue model or PPP concession model can be adopted whereas for recycling systems, other forms of finance are required. Similarly, to finance recycling businesses and exchanges, a wide range of investment size and types are required, for which the financing models needs to be flexible for both small and large-scale projects.

Global Environment Facility (GEF): GEF is a multilateral environment fund that was established more than three decades ago leading up to the 1992 Rio Earth Summit.

It is a financial instrument to support implementation of five major international environmental conventions: the Minamata Convention on Mercury, the Stockholm Convention on Persistent Organic Pollutants (POPs), the United Nations Convention on Biological Diversity (UNCBD), the United Nations Convention to Combat Desertification (UNCCD) and the United Nations Framework Convention on Climate Change (UNFCCC). It grants and blended finance for projects related to biodiversity, climate change, international waters, land degradation, persistent organic pollutants (POPs), mercury, sustainable forest management, food security, and sustainable cities in developing countries.

GEF supports country-driven priorities and initiatives and has funded more than 5,000 projects globally. GEF funding is typically routed through partner agencies such as United Nations agencies (UNDP, UNEP, UNIDO etc.) and development banks such as the World Bank, ADB etc. Developing countries are eligible to receive GEF support and implement projects that provide local and global environmental benefits.

GEF has supported over 100 projects in India through a mix of instruments such as grants, blended finance etc. Several of these projects focus on improving cities and urban environment. For example, Livable Cities in India: Demonstrating Sustainable Urban Planning and Development through Integrated Approaches is being implemented in cities of Surat, Pune, and Chennai to demonstrate low emissions, resilient, nature-based inclusive sustainable urban development in these cities and support its replication at national level. Specifically in waste management, in India GEF is supporting projects focused on management of medical waste, disposal of polychlorinated biphenyls (PCBs) and review and update on Persistent Organic Pollutants (POPs) for India.

13 Conclusion and Recommendations

> *"The strongest governments on earth cannot clean up pollution by themselves. They must rely on each ordinary person, like you and me, on our choices, and on our will.*
>
> *~ Chai Jin*

The amount of MSW generated in urban India is significant and growing, with only about half of it being treated. Untreated waste dumped in cities and elsewhere has significant climate and public health risks. It is therefore critical to integrate climate considerations in waste management policy, programs and urban planning frameworks.

The use of waste-to-energy (WtE) or co-processing of non-recyclable waste in cement kilns present better options compared to landfilling. Between the two, co-processing in cement kilns being a preferred option for its potential for material recycling and energy recovery, as well as its cost efficiency and low GHG emissions.

The utilization of RDF in cement kilns is widespread in Europe and is expanding to other parts of the world, such as Southeast Asia and China. The Indian cement industry has the potential to significantly contribute to waste management and reduction of greenhouse gas emissions by co-processing alternative fuels, particularly SCF or RDF, in cement kilns.

Swachh Bharat Abhiyan (Clean India Mission) has made significant progress, but there is still a long way to go, and there is a need for collective efforts from citizens, government, and other stakeholders to make India a cleaner and sustainable country.

The report presents four cost recovery models for managing segregated waste, emphasising the importance of the 'Polluter Pays' Principle and the need to consider the financial, environmental, and social costs of waste management. The models involve producing SCF or RDF from municipal solid waste and co-processing it in cement kilns or using it as fuel in waste-to-energy facilities.

The analysis shows that all four models are economically viable, with relatively modest increases in costs for consumers, and potential savings from coal substitution. Further refinements may be made at the local level to ensure that the costs are affordable and passed on in a fair and equitable manner. Overall, the report provides valuable insights into the different cost recovery models for solid waste management in cities, and it is recommended to conduct thorough analysis and research before arriving at actual costs.

The authors make the following recommendations:

- **Apply the 'Polluter Pays' Principle:** The cost of managing waste should be borne by the polluter, following the 'Polluter Pays' Principle. Therefore, policymakers should ensure that the cost of waste management is passed on to waste generators and not subsidised by the government.
- **Adopt a waste hierarchy based on circularity:** To achieve the goal of zero waste, it is critical to adopt a waste hierarchy based on circularity, which prioritises waste reduction, reuse, and recycling over disposal options like landfilling.

- **Promote waste-to-energy and co-processing:** The use of waste-to-energy (WtE) or co-processing for non-recyclable waste with high calorific value is seen as a better option than landfilling. Therefore, policymakers should promote the adoption of these technologies to reduce the amount of waste sent to landfills and increase energy recovery.
- **Given significant advantages,** co-processing should be the preferred option and WtE should be deployed where co-processing in cement kilns is not practically possible. Further, WtE design, operation, maintenance, and monitoring needs to be carefully regulated and managed to ensure compliancewith all laws and regulations.
- **Improve waste segregation and collection:** Waste segregation and collection are critical to the success of waste management programs. Therefore, policymakers should focus on improving waste segregation and collection efficiency to ensure that the waste is properly managed.
- **Encourage public-private partnerships:** Public-private partnerships can help bridge the gap between the government and private sector in waste management. Therefore, policymakers should encourage such partnerships to leverage the expertise and resources of the private sector in waste management.
- **Develop supportive regulatory frameworks:** A supportive regulatory framework is essential to encourage businesses to invest in the infrastructure and technology necessary to make co-processing of waste in cement kilns a sustainable and viable option. Therefore, policymakers should develop such frameworks to create a conducive environment for the growth of the waste management industry.
- **Conduct due-diligence:** The assumptions used in the cost recovery models for waste management are based on industry estimates and MoHUA guidelines. Therefore, it is recommended to conduct due-diligence as part of any investment analysis since the actual costs may vary depending on market conditions, credit ratings, and other factors.

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Source: SINTEF

15 Annexure

Table 15.1: State-wise list of dumpsites in India						
State/UT	**No. of dumpsites**	**Area (Acre)**	**Legacy waste qty (Mt)**	**Remediated waste qty (Mt)**	**Waste to be remediated (Mt)**	**Waste to be remediated (%)**
A&N Islands	1	3	0.07	0.01	0.06	86%
Andhra Pradesh	128	1,082	85.9	11.18	74.72	87%
Arunachal Pradesh	9	49	0.36	0.17	0.19	53%
Assam	21	119	25.49	0	25.49	100%
Bihar	45	243	26.13	4.15	21.98	84%
Chandigarh	2	28	12.77	5.24	7.53	59%
Chhattisgarh	13	85	7.18	4.21	2.97	41%
DD&DNH	2	7	1.42	0	1.42	100%
Delhi	3	202	203	76.98	126.02	62%
Goa	6	16	18.09	1.37	16.72	92%
Gujarat	138	981	235.97	105.74	130.23	55%
Haryana	91	408	107.35	47.85	59.49	55%
Himachal Pradesh	11	21	2.68	0.66	2.02	75%
Jammu And Kashmir	12	357	18.86	2.34	16.52	88%
Jharkhand	36	121	31.15	0.35	30.81	99%
Karnataka	195	1,164	182.64	0.02	182.62	100%

State/UT	No. of dumpsites	Area (Acre)	Legacy waste qty (Mt)	Remediated waste qty (Mt)	Waste to be remediated (Mt)	Waste to be remediated (%)
Kerala	31	149	12.6	0.11	12.49	99%
Ladakh	1	28	1.32	0	1.32	100%
Madhya Pradesh	168	857	61.86	8.74	53.12	86%
Maharashtra	220	1,540	531.96	149.83	382.13	72%
Manipur	5	26	1.6	0	1.6	100%
Meghalaya	10	12	4.82	0	4.82	100%
Nagaland	13	61	8.62	0	8.62	100%
Odisha	44	268	32.96	2.71	30.25	92%
Puducherry	4	59	12.09	0.6	11.49	95%
Punjab	106	513	74.3	21.31	52.99	71%
Rajasthan	179	1,630	75.71	2.33	73.37	97%
Sikkim	2	38	2.86	0	2.86	100%
Tamil Nadu	299	2,173	233	74.56	158.44	68%
Telangana	103	1,167	153.29	121.4	31.89	21%
Tripura	15	37	4.44	0.2	4.24	95%
Uttar Pradesh	185	4,325	104.45	55.75	48.69	47%
Uttarakhand	25	83	18.44	0	18.43	100%
West Bengal	120	73	146.32	7.88	138.44	95%
Total	2243	1852	2439.7	705.69	1733.98	71%

Source: SBM (U) 2.0 Dashboard

Table 15.2: List of WtE plants in India

SN	State	Plant Location	Year of Commissioning	Power Generation (MW)	Capacity (TPD)	Remarks
1	Andhra Pradesh	Visakhapatnam (4 ULBs)	2022	15	1133	
2	Andhra Pradesh	Guntur (9 ULBs)	2022	15	1202	
3	Assam	Guwahati (proposed site)		Nil	300	Proposed
4	Bihar	Patna- Ramchak Bairya	2025	Nil		Under Planning
5	Chhattisgarh	Raipur	2020	12	700	Operated under PPP
6	Goa	Sailogo, Bardez, Goa	2016	0.6	100	In operation
7	Gujarat	Surat	2024	12	1000	Permitting stage
8	Haryana	Sonepat	2021	7	750	Operational (PPP model)
9	Haryana	Gurugram (Bhandwari)	2024	23	750	Under Installation
10	Himachal Pradesh	Shimla		1.75	100	Under trials
11	Himachal Pradesh	Manali		1		Under Construction
12	Karnataka	Kannahalli	2021	40	1000 (500- 700 processed)	Operational (partially)
13	Kerala	Kozhikode				Work awarded
14	Kerala	Kannur				Work awarded
15	Kerala	Kollam				Work awarded
16	Kerala	Palakkad				DPR stage
17	Kerala	Kochi				Re-tendering completed
18	Kerala	Thiruvananthapuram				Land not identified
19	Kerala	Munnar				Tendering
20	Kerala	Thrissur				Land identified
21	Kerala	Malappuram				Land identified
22	Madhya Pradesh	Jabalpur	2016	11.5	600 (400 processed)	Operational
23	Madhya Pradesh	Rewa (2)		2x6		Under Construction
24	Maharashtra	Solapur Municipal Corporation	2013	4	400 (200-250 processed)	In Operation

SN	State	Plant Location	Year of Commissioning	Power Generation (MW)	Capacity (TPD)	Remarks
25	Manipur	Lamdeng, Imphal	2022	2.4	300	Under Installation
26	Punjab	Bathinda		-	350	Both plants are not operational
27	Punjab	Ludhiana		-		
28	Rajasthan	Jaipur		6	600	PPA &. Lease deed pending
29	Rajasthan	Jodhpur		3	400	PPA & Lease Deed pending
30	Telangana	Jawaharnagar, Hyderabad	2020	19.8	1200	Permit until 2025
31	Telangana	Chennaravulapally, Bibi Nagar		11	1000	Pre-commissioning stage
32	Telangana	Yacharam, Ibrahimpatnam		12	700	
33	Telangana	Rebladevpally, Sultanabad		12		Not operational- non-viability of tariff.
34	Telangana	Suryapet		12.6		Not operational- non-viability of tariff.
35	Telangana	Dundigal		14.5		Construction work not yet started
36	Uttarakhand	Haridwar		5		Proposed- use RDF of Roorkee and other towns
37	Uttarakhand	Dehradun		-		Proposed
38	Uttar Pradesh	Barabanki		2.5	55	Operational
39	Uttar Pradesh	Meerut		2.5		Operational
40	Chandigarh	Dadumajra, Sector-25 West, Chandigarh			60	Used in own hot air generator- rest sent to other industries
41	Delhi	Okhla	2012	23	2000 (1818 processed)	Operational, faced protests by residents in past
42	Delhi	Ghazipur	2016	12	1300 (502 processed)	Operational
43	Delhi	Bawana	2017	24	1400 (756 processed)	Operational- Biggest WtE plant in India
44	Delhi	Narela	2025	25	3000	Under construction.

Source: CPCB Annual Report 2020-21 on Implementation of SWM Rules 2016, CSE Report 2018, Various news articles

Source: RTI

Credit: RTI

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