Sustainable Organic Waste Management

A Playbook for Lucknow, India

Report / March 2024

Authors and Acknowledgements

Authors

Ebun Ayandele
Jyoti Bodas
Shweta Gautam, The Energy and Resources Institute
Videesha Velijala, The Energy and Resources Institute

Authors listed alphabetically. All authors from RMI unless otherwise noted.

Contributors

Tom Frankiewicz, RMI
Yuchen Wu, RMI
Dr. Suneel Pandey, The Energy and Resources Institute

Contacts

Ebun Ayandele, eayandele@rmi.org
Shweta Gautam, shweta.gautam@teri.res.in

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Shweta Gautam, Ebun Ayandele, Videesha Velijala, and Jyoti Bodas, *Sustainable Organic Waste Management: A Playbook for Lucknow, India*, RMI, 2024, **https://rmi.org/insight/waste-methane-assessment-platform/**.

Acknowledgements

The authors would like to thank the Global Methane Hub (GMH) for its generous funding support, which made this report possible. The authors would also like to thank The Energy Resources Institute (TERI), the local partner in India, for its immense contribution to this project.

The authors wish to thank the individuals and organisations who provided valuable feedback on this work.

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The Waste Methane Assessment Platform (WasteMAP), a joint initiative by RMI and Clean Air Task Force, is an open online platform that brings together waste methane emissions data with decision support tools for stakeholders in the waste sector. The platform is supported by country engagement that involves collaboration with national and subnational governments, waste management officials, and other key decision makers to provide capacity building and technical assistance — providing a pathway to reduce solid waste methane emissions. Please visit our website **www.wastemap.earth** to learn more.

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Executive Summary

In 2020, 2.24 billion tonnes of municipal solid waste (MSW) were generated globally, and this number is projected to reach 3.88 billion tonnes by 2050 with much of this increase driven by the fastest-growing regions, including sub-Saharan and North Africa, South Asia, and the Middle East, where waste is expected to double or even triple current levels.

As the most populous country in the world, India currently generates 62 million tonnes of MSW annually — a majority of which is sent to landfills — and that number is projected to reach 436 million tonnes by 2050. Improper disposal of waste pollutes soil, air, and water, posing health and safety hazards to nearby communities. Thus, India needs to deploy more sustainable waste management systems to ensure that it can adequately handle its increasing volumes of waste.

Beyond the immediate public health and safety risks, unsustainable waste management also has far-reaching climate impacts. The organic fraction of this waste, including food waste, yard waste, paper, and cardboard, generates landfill gas (LFG) comprising methane and carbon dioxide when it decomposes in landfills and dumpsites, which is then released into the atmosphere if not properly captured.

This playbook provides concrete, actionable strategies to improve organic waste management in Lucknow, the capital and largest city in the Indian state of Uttar Pradesh, the most populous state in the country. First, it provides a brief overview of current MSW management practices with a focus on organic waste. Next, it explores opportunities across the value chain to improve how organic waste and MSW emissions are managed by leveraging the strategies outlined in RMI's ***A Playbook for Municipal Solid Waste Methane Mitigation: Recommendations Based on Global Waste Management Archetypes*** for the so-called Build the Basics Plus (BtB+) archetype, which characterises the MSW management landscape in India.

These strategies are organised based on the waste management value chain: waste generation, collection and transport, recovery and treatment, and disposal, as well as a crosscutting component that explores policy and regulatory frameworks, data transparency, finance, and stakeholder awareness and capacity-building opportunities. Together, the strategies provide a holistic approach to recovering organic waste and reducing emissions in the waste sector after the point of waste generation (see Exhibit ES1).

Exhibit ES1 Scope of organic waste management strategies

RMI Graphic. Source: RMI analysis

The playbook explores strategies to improve separation of organic waste at the source, enhance waste collection efficiency, expand organics processing capacity, and optimise design and operation at disposal sites to minimise fugitive emissions. Further, it highlights the importance of developing an enabling policy environment, improving data transparency, increasing access to affordable finance, and building stakeholder awareness and capacity. The authors also explore the roles of key stakeholders in implementing these strategies.

To conclude, the authors recommend three key levers for improving organic waste management in Lucknow and better aligning current management practices with the waste management hierarchy. These levers include rehabilitating dumpsites to sanitary landfills, developing technical capacity among waste service providers, and access to affordable finance. Enforcing India's Solid Waste Management Rules, enacted in 2016, is essential for achieving sustainable management of organic waste. At the same time, upgrading the city's dumpsite to a sanitary landfill with gas collection system will ensure that the emissions from nondiverted waste are captured for beneficial end use. Finally, affordable financing is critical for deploying and scaling infrastructure to collect and treat organic waste and capture LFG emissions. However, given that access to affordable finance is a major barrier to implementation, the city of Lucknow can begin advancing sustainable waste management by deploying decentralised organic waste treatment solutions like small-scale composting and anaerobic digestion facilities that do not require large investments.

These actions can shift the approach to waste management in Lucknow, protect environmental safety and human health, and help advance the city towards a low-carbon economy.

1. Introduction

Global municipal solid waste (MSW) was estimated at 2.24 billion tonnes in 2020, and this number is projected to increase by 70% to almost 3.88 billion tonnes by 2050.[1] Much of the increase will be driven by the fastest growing regions, including sub-Saharan and North Africa, South Asia, and the Middle East, where waste is expected to double or even triple current levels.[2]

Now the most populous country in the world, India generates 62 million tonnes of MSW annually, the majority of which is sent to landfills and dumpsites — many of which are fast approaching capacity.[3] With its waste generation projected to reach 436 million tonnes annually by mid-century, India's growing population and urbanisation have been key drivers of its increasing use of resources and highlight the need for sustainable waste management systems.[4]

Efforts to reduce waste generation and recover materials should be prioritised over disposal at landfills and dumpsites. Recovering discarded materials that will otherwise end up at disposal sites will reduce the burden on energy systems, food systems, global supply chains, and waste systems. However, material recovery is often limited to traditional recyclables like plastic, glass, metals, paper, and cardboard, often missing an opportunity to recover biodegradable food and yard waste. Indiscriminate disposal of biodegradable waste pollutes the soil, water, and air, further underscoring the need for sustainable waste management alternatives.

According to the United Nations Environment Programme *Food Waste Index* report, an estimated 13% of the world's food is lost before it reaches consumers, and another 17% is wasted or discarded in households, food services, and retail, after it reaches consumers.[5] In India, food waste makes up 44% of the MSW stream in urban areas.[6] Therefore, recovering food waste can significantly lower the total amount of MSW sent to these disposal sites, provide valuable energy resources and soil benefits, and improve food security and the welfare of farmers, producers, and consumers. Diverting food waste and other biodegradable waste from disposal sites also provides climate benefits by reducing greenhouse gas (GHG) emissions from the decomposition of this waste at disposal sites. Projections for the Swachh Bharat Mission (Urban) 2.0[i] estimate that 45,000 tonnes per day (TPD) of processing facilities are required to adequately treat biodegradable waste in India, illustrating the significant opportunity for sustainable waste management, particularly in urban metropolises.[7]

This report aims to outline a pathway for improving organic waste management in Lucknow, India, after the point of waste generation (see Exhibit 1). The report serves as a playbook for key decision makers in Lucknow and recommends actionable strategies to sustainably manage organic waste and emissions from this waste that are tailored to India's solid waste management archetype. The strategies are intended to support decision makers in improving waste management and protecting public health in Lucknow — a city that is already an economic hub and can represent a path to sustainable waste management for other Indian cities, especially in working towards the goal of "Garbage Free Cities," as part of the Swachh Bharat Mission (Urban) 2.0.[8]

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i The Swachh Bharat Mission (Urban) 2.0, launched in 2021, is a five-year plan to clean up Indian cities with a vision to become garbage free, thereby improving the quality of life for urban populations. The plan is an extension of the original Swachh Bharat Mission, which launched in 2014.

Exhibit 1 The municipal solid waste value chain

RMI Graphic. Source: RMI analysis

2. Overview of Municipal Solid Waste Management Landscape

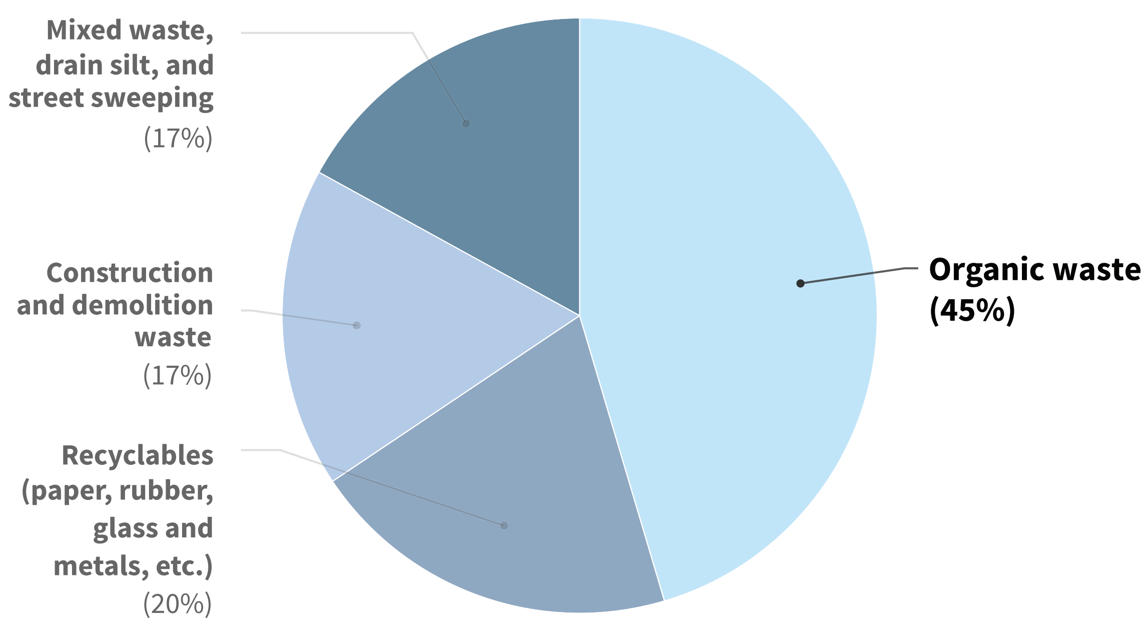
With a projected population of 4.5 million — estimated to reach about 6 million by 2031 — the city of Lucknow is the capital and largest city in the Indian state of Uttar Pradesh, the most populous state in the country.[9] The city serves as the administrative centre for Lucknow District and Lucknow Division.[10]

Rapid urbanisation and population growth have driven a substantial increase in waste generation. The Lucknow Municipal Corporation (LMC), which consists of 110 wards, oversees the city's civic infrastructure and administration, including waste management activities from waste collection and transport, recovery and treatment, and disposal. The following section explores waste management practices in Lucknow.

Waste Generation

In 2022, Lucknow generated about 2,000 TPD of MSW, excluding construction and demolition waste.[11] Sources of MSW include households, restaurants, street cleaning activities, markets, shops and workshops, offices, hospitals, and hotels.[12] Of the total waste generated, about 45% is organic matter, which represents the largest component of the waste stream (see Exhibit 2). Recyclable materials including plastics, metals, glass, and paper make up 20%, while construction and demolition debris and mixed waste, like drain silt and street sweepings, each make up nearly 17% of total waste generated.[13] The city operates a two-bin system to collect dry waste and wet waste.

Exhibit 2 **Municipal solid waste composition in Lucknow**



RMI Graphic. Source: *Current World Environment*, https://cwejournal.org/pdf/vol14no3/Vol14_No3_p_421-432.pdf

Waste Collection and Transport

Lucknow has a waste collection efficiency of 60%.[14] MSW is retrieved by the urban local body (ULB)[ii] via door-to-door collection and through secondary collection from designated points such as community bins, waste storage depots, and transfer stations. Once collected, either via door-to-door collection or from secondary collection points, the waste is transported directly to Shivari, which serves as the waste processing and disposal facility in the city. In addition, waste pickers informally retrieve recyclable materials via door-to-door collection, from community bins, or from dumpsites, and then sell them to junk shops or "kabadiwalas" who segregate the waste for further processing by recycling companies.

The city has three transfer stations — in Gwari, Malpur, and Priyadarshan Colony — although only the one in Gwari is currently operational. To enhance transportation efficiency, GPS systems have been installed in LMC collection vehicles, which include hauled containers, stationary containers, manually loaded dumpers, and mechanically loaded dumper systems. Lucknow also has several portable compact transfer stations consisting of a compactor and a container body distributed around the city to ease localised waste collection and transportation to the Shivari facility.[15]

Waste Recovery and Treatment

The plant at Shivari, with a design capacity of 2,200 TPD, processes newly generated waste and legacy waste. The legacy waste is transformed into various end products, including biosoil, compost, inert waste used for road construction filling, and refuse-derived fuel. The fuel is sold at INR 1,000/tonne and serves as an energy source for boilers in brick and tile facilities and to produce pavement blocks. Similarly, the biosoil generated is sold at INR 500 per truck, regardless of the truck's size.

Notably, because the plant has limited capacity, the dumpsite has a substantial amount of legacy waste — an estimated 1.85 million tonnes.[16] As part of a short-term action plan to manage legacy waste, LMC has bioremediated about 48,000 tonnes of waste. However, to enhance the city's processing capacity, LMC is constructing a 6,000 TPD processing plant for the bioremediation of legacy waste. Further, a 1,250 TPD plant has been installed by LMC to produce compost from newly generated waste. Each month, the plant sells about 500 tonnes of compost to fertiliser companies at about INR 1,600 per tonne.[17]

Waste Disposal

In Lucknow, indiscriminate dumping of waste is common and burning of waste is not unusual despite LMC prohibiting the open burning of waste.[18] An inadequate waste collection system results in the illegal disposal of waste in the streets and water channels, posing significant health risks in the city. This problem is exacerbated by the limited processing capacity at the Shivari plant, which leaves an estimated 800 TPD of newly disposed of waste unprocessed. This waste continues to accumulate at the plant, becoming an impediment to the city's waste management efforts. In response to this challenge and in compliance with India's Solid Waste Management Rules of 2016 (SWM Rules, 2016), LMC has efforts underway, as discussed in the waste recovery and treatment section above, to increase the processing capacity of waste and extend the life span of Shivari dumpsite.[19]

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ii Urban local bodies are the local governing bodies of urban areas in India.

Organic Waste Management

Implementing sustainable waste management practices can help reduce the volume of waste in landfills and offer environmental and human health benefits to the city. These techniques centre around the diversion of organics and recovering the resources through treatment for alternative end uses.

Although there are many technologies currently deployed to treat solid waste and/or stabilise the organic waste fraction prior to reaching disposal sites, such as mechanical biological treatment, waste-to-energy systems, and advanced thermal treatment, the two most common and suitable options for managing organic waste in Lucknow are composting and anaerobic digestion (AD). Waste-to-energy and advanced thermal treatment should not be considered as treatment options for organic waste due to concerns of toxic air pollutants that can lead to severe health conditions like cancer and birth defects, especially in nearby marginalized communities.[20] Further, incinerating organic waste lowers the calorific value of the fuel due to the high moisture content of the wet waste and represents a loss of carbon and plant nutrients that could be applied to the soil.

- Composting is a controlled aerobic process (i.e., oxygen is present) that involves the microbial decomposition of organic material like leaves, grass clippings, and food scraps to convert the organic substrate into compost. Compost provides nutrients to soil in a manner that is readily useful to plants.

- AD is the microbial decomposition of organic waste in the absence of oxygen. This process, which occurs naturally in landfills and dumpsites, takes place in enclosed biodigester tanks where the biodegradable waste is converted into biogas. The biogas can be combusted to generate electricity and heat or can be processed into renewable natural gas and transportation fuel.[21] The digestate co-product can be used as a soil enhancer for agricultural purposes.

Organic Waste Treatment Operations in Lucknow

Lucknow is the largest city in Uttar Pradesh, the most populous state in India, and generates more than 2,000 tonnes of solid waste every day.[22] Organic waste makes up almost half of the MSW in Lucknow (see Exhibit 2). Given rapid urbanisation, a dense and growing population, and a growing waste generation level in Lucknow, diverting organic waste and recovering its resources would directly reduce the burden on the city of accumulating unprocessed waste.[23] Proper organic waste management can also provide social, economic, environmental, and human health benefits, including reduced odour, disease-carrying vectors, and groundwater contamination from toxic leachate, as well as beneficial end products from recovery of organic matter.

LMC has demonstrated a commitment to advancing sustainable waste management in Lucknow by placing compost pits in parks to promote the use of compost and bioremediating legacy waste. LMC has also initiated the construction of a 300 TPD bio compressed natural gas (CNG) plant and a 100 TPD biogas plant in Gobar to manage the city's biodegradable waste. However, the need to increase waste collection efficiency and waste processing capacity at Shivari remains, demonstrating the importance of continuing and expanding organic waste management efforts.

The case study below describes operations at the Kanha Upwan Biogas Plant in Lucknow.

Case Study: Kanha Upwan Biogas Plant, Lucknow

The Kanha Upwan Biogas Plant, established in 2015, is a government-run initiative that converts organic waste into energy and fertiliser. Employing a fixed-dome reactor technology, the plant processes 4,440 kg/day of organic waste, including dung, dead animals, and sewer waste.[24]

The biogas powers a generator that in turn is used to power the plant's operation. The remaining biogas is used to meet the cooking and electricity needs of 40 local families and provide cooking gas to a canteen that caters to 200 individuals. Surplus biogas is stored in a dedicated tank.[25] The solid by-product is treated and either repurposed as manure or used to create incense sticks (see Exhibit 3) and small oil lamps (diyas).

The Kanha Upwan Biogas Plant provides a model for sustainable organic waste management and innovative resource utilisation.

Exhibit 3 **Incense sticks made from solid digestate by-product**

Source: TERI and RMI site visit

3. Opportunities for Improving Organic Waste Management in Lucknow

With growing populations driving increasing waste generation, there is a need to implement more sustainable approaches to waste management across the globe. This issue is more dire in densely populated cities like Lucknow.

Waste management in India falls under the Build the Basics Plus (BtB+) archetype (see Exhibit 4). Although this archetype shares certain characteristics with the Build the Basics (BtB) archetype in its approach, BtB+ countries demonstrate relatively more advanced waste management practices. The main differences include higher collection rates and a clear progression from dumpsites to sanitary landfills. Countries in the BtB+ archetype have taken major steps towards improving their solid waste management, such as building sanitary landfills or expanding existing waste management laws and regulations to address organic waste, advancing them beyond the BtB archetype. However, although there are efforts underway to deploy and expand waste treatment technologies, treatment of waste is still limited. The primary approach to waste management is disposal at dumpsites; illegal disposal and open burning of waste are still common. Consequently, there is a need to deploy more robust waste treatment technologies and expand the ongoing upgrade of dumpsites to sanitary landfills. As with the BtB archetype, access to funding to build critical infrastructure is often a major roadblock for many BtB+ countries seeking to improve their waste management practices. For more information on this and other waste management archetypes, see ***A Playbook for Municipal Solid Waste Methane Mitigation: Recommendations Based on Global Waste Management Archetypes***.

Exhibit 4 Global municipal solid waste management archetypes

Build the Basics (BtB)

- Low to medium waste collection rates
- Limited or no source-separated organics or recycling
- Limited or no waste treatment
- Waste is disposed of at dumpsites
- Illegal dumping and open burning of waste are common

Build the Basics Plus (BtB+)

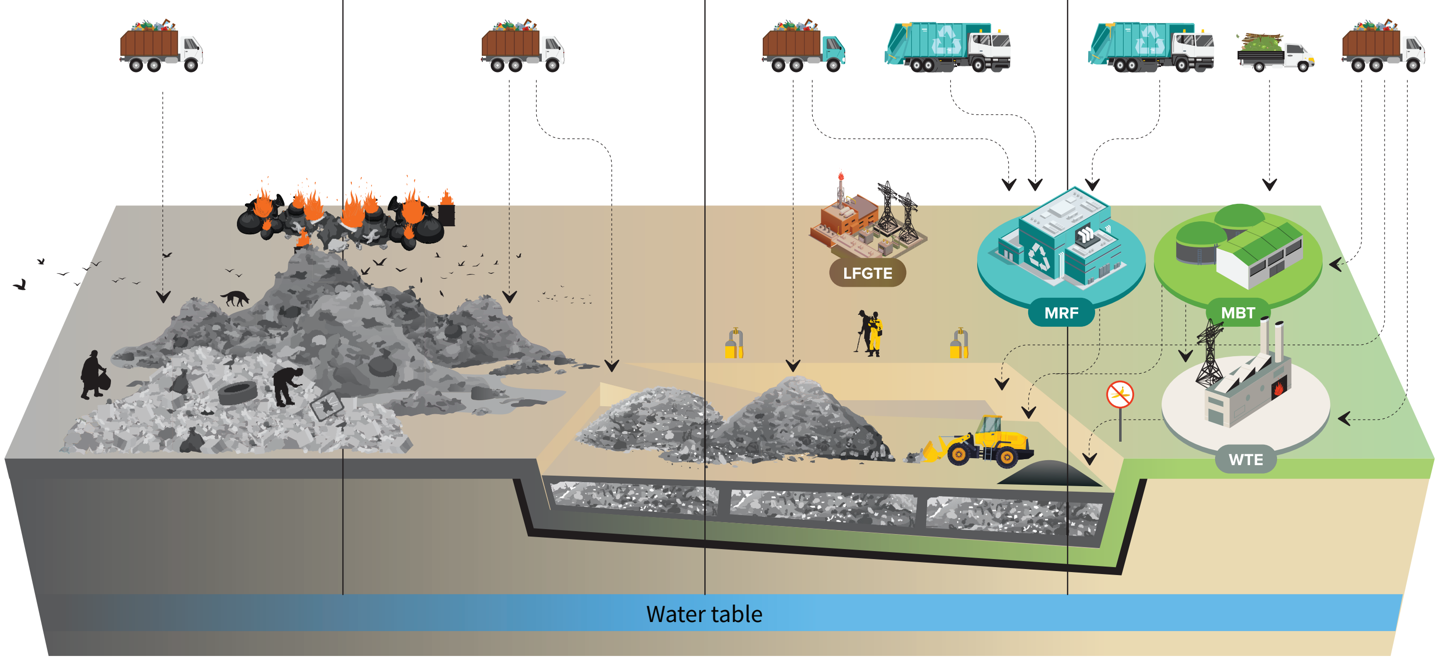
- Higher waste collection rate than BtB
- Limited or no source-separated organics or recycling
- Limited waste treatment
- Transitioning from dumpsites to sanitary landfills
- Illegal dumping and open burning of waste may occur

Move up the Hierarchy (MuH)

- Universal or near-universal waste collection
- Higher source-separated organics and recycling rates than BtB and BtB+; source-separated organics is still relatively limited compared to CtC
- Waste treatment and material recovery facilities are common
- Waste is disposed of in sanitary landfills
- Methane emissions monitoring and capture may occur

Close the Circle (CtC)

- Universal or near-universal waste collection
- In most CtC countries, source-separated organics and recycling rates are higher than in BtB and BtB+ countries and source-separated organics is mandated by law
- Most CtC countries have banned biodegradable waste from landfills
- Mechanical biological treatment and incineration of waste are common
- Least reliant on landfills



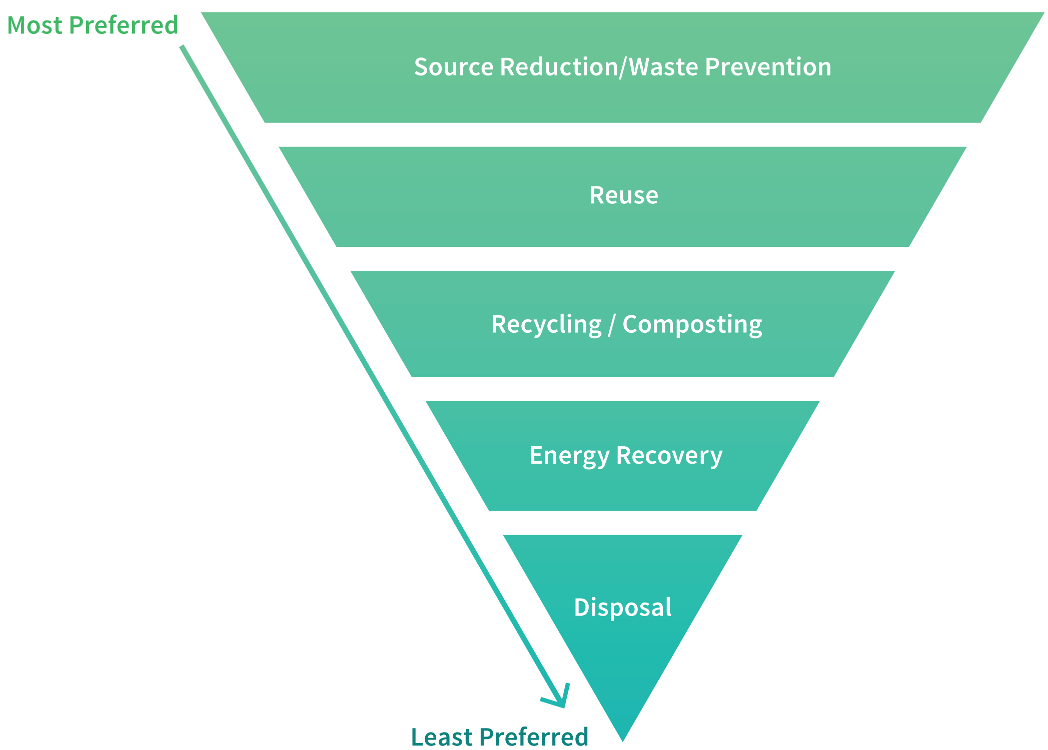
Waste collection, treatment, and disposal activities occur at different sites. Note that the primary outputs from the materials recovery facility and the mechanical biological treatment plant (e.g., plastics and biogas) are not depicted. The graphic has been simplified for illustrative purposes.

RMI Graphic. Source: RMI analysis

Despite these constraints, BtB+ countries like India can improve their waste management practices and align their approach more closely with the waste management hierarchy by continuing the upgrade of dumpsites to sanitary landfills and implementing more stringent requirements on LFG capture and control. Conducting routine reviews and updates of existing MSW-related policies and regulations can help identify implementation gaps and strengthen the policy environment to promote sustainable management of organic waste while also addressing the emissions from the decomposed waste.

Although this report explores opportunities to improve organic waste management after waste has been generated, it is important to emphasise that source reduction, which minimises the generation of waste, is the preferred and most cost-effective solution to managing organic waste and its associated emissions. Understanding the underlying causes that lead to food loss and waste — including poor harvest and post-harvest techniques, insufficient distribution and storage infrastructure, lack of cooling and refrigeration, poor food management, and consumer behaviours — is essential to develop robust solutions. Following source reduction, reuse and recycling are the next best options. These solutions enable the conversion of organic waste to beneficial end products while also addressing food insecurity and malnutrition in local communities, and improving the economic welfare of farmers, producers, and consumers. Exhibit 5 depicts the waste management hierarchy, which prioritises waste management solutions from most to least environmentally favourable option.

Exhibit 5 Waste management hierarchy



RMI Graphic. Source: RMI analysis

Exploring opportunities to improve organic waste before it is generated is beyond the scope of this report. However, several opportunities exist to improve organic waste management after it has been generated. The strategies described in the following section are organised to reflect such opportunities throughout the MSW value chain including waste generation, collection and transport, recovery and treatment, and disposal. Further, this playbook also explores crosscutting opportunities that span the entire value chain including policy and regulatory framework, data transparency, finance, and stakeholder awareness and capacity building. These insights were derived from comprehensive desk research and in-depth interviews with key stakeholders such as landfill operators, dumpsite managers, plant operators, technology providers, government agencies, regulatory bodies, and academic institutions. These strategies aim to promote a circular economy that converts waste resources into useful end products that provide economic as well as environmental, health, and climate benefits. Further, the playbook describes the roles and responsibilities of key stakeholders in promoting sustainable waste management practices.

Waste Generation

In Lucknow, organic waste constitutes the largest fraction of the MSW stream. Once waste is generated, diverting the wet organic fraction from landfills and dumpsites is preferable to managing the impacts of the decomposed waste at the disposal sites. The process of diverting organic waste should ultimately begin with the waste generators by involving them in segregating various waste components as soon as the waste is generated.

1. Implement Source-Separated Organics Programmes

Separating organic waste at the source involves placing biodegradable components into designated bins at the point where the waste is generated. Efficient source segregation minimises contamination and the cost associated with downstream sorting, ensuring a clean feedstock for processing, thereby enhancing the treatment efficiency and the quality of products derived from organic materials. Minimising contamination, such as glass and plastics, is crucial for successful source-separated organics (SSO) programmes because heavily contaminated waste streams result in low-quality end products that may be undesirable to end-users and diminish the economic feasibility of organics recycling.

The main obstacles to SSO in Lucknow are a lack of awareness among waste generators on sorting waste, inadequate collection infrastructure for proper compartmentalization of waste during pickup and transport, as well as an insufficient amount of such collection vehicles to handle the city's waste. LMC can achieve effective source segregation by actively involving the community, providing designated bins, expanding infrastructure to handle segregated waste, and training waste generators on effective waste segregation techniques (see Exhibit 7). Beyond providing bins and improving awareness among waste generators, ULBs can incentivise SSO by implementing rewards and/or a penalty system to promote participation and compliance. For example, a reward and recognition system may provide food or gift vouchers or publicly recognize those who properly segregate their waste and impose fines on those that fail to properly segregate their waste. Such fines can be imposed on residential welfare associations (RWAs) and BWGs that fail to comply.

Case Study: Indore's Path to Sustainable Waste Management — Achieving 100% Source Segregation

Recognised as the cleanest city in India in every Swachh Survekshan (cleanliness) survey since 2017, the city of Indore sets an example for excellent MSW management, from source segregation to waste processing. The approach for improving waste management in the city started as a pilot project, with door-to-door collection implemented in two wards, which was then extended to a few more wards and eventually to the entire city, along with continuous awareness programmes on segregation of wet and dry waste. The city initially used a two-bin system for separate collection of wet and dry waste, per the Swachh Bharat Mission guidelines, and eventually expanded its waste segregation to include a third bin for sanitary and hazardous wastes (see Exhibit 6). Source segregation coupled with composting and AD of biodegradable waste has contributed to the diversion of 630 TPD of biodegradable waste from dumpsites.

To achieve these results, Indore Municipal Corporation undertook extensive awareness campaigns through radio jingles, wall paintings, and street plays. Cultural events were used to disseminate messages and religious and community leaders were engaged to talk about cleanliness as commanded in religious books. Information, education, and communication activities were continuously monitored to assess their impact.

Other initiatives contributing to Indore's success include supplying designated waste bins at subsidised rates, awarding "zero-waste" tags to markets and colonies that excel in waste management, using a mobile app for complaint and grievance redressal with the status of complaints monitored by the municipal commissioner, and fines and penalties imposed on litterbugs and noncompliers.[26]

Exhibit 6 **A compartmentalised collection vehicle for separate collection and transport of different waste components**

Source: NITI Aayog and CSE, https://www.niti.gov.in/sites/default/files/2021-12/Waste-Wise-Cities.pdf

Exhibit 7 Stakeholder roles and responsibilities, waste generation

Stakeholder Group	Roles and Responsibilities
LMC and waste service providers	• Provide colour-coded bins. • Create educational programmes and public awareness campaigns to promote participation.
Waste generators (e.g., households, Resident Welfare Associations, commercial centers, and BWGs)	• Segregate organic waste into designated bins. • Participate in educational awareness programmes to improve understanding about how to effectively segregate waste.

RMI Graphic. Source: RMI analysis

Waste Collection and Transport

After waste generators have placed the wet organic fraction in the designated bins, SSO programmes should ensure its separate collection and transportation to processing facilities to reduce cross contamination. This entails having adequate infrastructural capacity and assessing collection routes and frequency to optimise the collection process (see Exhibit 8).

1. Expand Waste Collection Infrastructure

Effectively segregating organic waste at the source requires specialised leak-proof vehicles that can transport the wet organic fraction to a processing facility. To accommodate these needs, the city would need to either purchase these specialised vehicles or modify existing collection trucks to collect biodegradable and non-biodegradable waste separately. Deploying these specialised vehicles enhances the efficiency of the treatment process by reducing contamination from the residual mixed-waste stream.

Waste haulers should also take into account the differences in amounts of waste generated between communities and individual households, the source of organic waste and its impact on contamination levels, and the local conditions such as road networks and traffic patterns to optimise collection efficiency.

2. Optimise Collection Frequency and Route

Collection and transport account for a significant portion of the total cost of solid waste management.[27] Separate collection of the segregated wet fraction, which involves dual trips and longer hauling distances can deter waste collectors due to the increased cost. This cost is passed on to the waste generators who may be reluctant to pay additional costs. Optimising the frequency of collection and routes taken can reduce the number of trips, number of personnel, time spent, and distance travelled and help reduce operational cost and pollution.

LMC should consider strategies that facilitate timely collection and encourage waste generators to separate their decomposable waste, such as more frequent collection of biodegradable waste compared with residual mixed-waste or dry recyclables. This simple strategy can incentivise generators to properly segregate the biodegradable waste, because placing biodegradable waste into mixed-waste bins results in unpleasant odours and flies due to longer pickup times.

Exhibit 8 Stakeholder roles and responsibilities, waste collection

Stakeholder Group	Roles and Responsibilities
Waste generators (e.g., households, Resident Welfare Associations, commercial centers, and BWGs)	• Hand over segregated waste directly to collectors or place waste bins curbside for collection, where applicable.
LMC and waste service providers	• Evaluate collection infrastructure (e.g., number of collection trucks and GPS) and personnel needed, as well as the cost of deployment. • Evaluate the most efficient routes for waste collection vehicles via mapping and planning. • Assess funding needs to expand collection infrastructure and seek funding, if needed.

RMI Graphic. Source: RMI analysis

Waste Recovery and Treatment

Along with strategies like SSO, effectively managing organic waste relies on treating the wet organic fraction for processing into useful products. India generates about 75,000 TPD of wet waste.[28] The Swachh Bharat Mission (Urban) framework estimates that about 68% of this waste is processed, while the remaining waste is untreated. Projections for the Swachh Bharat Mission (Urban) 2.0 estimate that 45,000 TPD of processing facilities is required to adequately treat wet waste.[29] Lucknow can help address this gap by deploying composting and AD, the two most common organic waste treatment technologies. Composting is a simpler and cheaper process and can be performed at the household level, while AD involves more sophisticated technology and a larger initial investment. However, both can be deployed at various scales. The organic fraction of MSW can be profitably converted to useful products like compost, biogas, and digestate. Additionally, leveraging economic tools such as procurement standards and setting minimum purchase targets for government agencies can expand the market for these end products.

The appropriate treatment option depends on an array of factors: climate, economic feasibility, available financing, land availability, waste composition, feedstock characteristics, preferred energy-recovery method, and end-user needs.

1. Develop Centralised and Decentralised Organic Waste Processing Facilities

Lucknow has an opportunity to process its organic waste using AD or composting technology. Depending on the needs and available funding, these plants may be small scale, medium scale, or large scale and can be deployed for various uses including treating household waste, canteen waste, and market waste. The nutrients from the compost can be used to enrich the soil and promote local agriculture and landscaping. Similarly, the biogas produced from the digestion process can provide a clean energy source for cooking, electricity, or direct heating.

Both small-scale and large-scale systems can be deployed to achieve widespread implementation. However, centralised large-scale systems often require an initial investment that may pose a barrier to implementation. Decentralised small-scale systems provide a cost-effective alternative to deploy waste treatment technologies. For example, composting can be deployed at the household, community, ward, and zone level to encourage SSO and better management of organic waste. Similarly, small-scale digesters can be deployed at fruit and vegetable markets to process their waste.

2. Support End Markets for Organic Waste–Derived Products

Organic waste–derived products like compost, biogas, and organic fertilisers often compete with other products, like synthetic fertiliser or diesel, that have a more established market and customer base. Without robust markets to enable demand and supply of products and guarantee a return on investment, organics diversion solutions will not achieve scale.[30]

However, these markets are nascent and often require economic and policy incentives like subsidies or tax credits to stimulate development until markets can be financially sustainable (see Exhibit 11). For example, the Government of India can provide subsidies and tax credits to encourage private sector investment and help defray project costs, making it easier for organic-based products to be cost-competitive and generate a return for investors, until the market is mature enough to operate without subsidies. Further, the Department of Agriculture in Lucknow can support end markets by mandating local government agencies to purchase a minimum amount of compost or digestate annually from local producers for use in agriculture, landscape restoration, and landfill covers as a means of stimulating demand. Additionally, the Uttar Pradesh government can establish procurement standards to ensure these products meet minimum quality standards to bolster customer confidence and promote product uptake.[31]

Case Study: The Bio-CNG Plant in Chetpet, Chennai

The Greater Chennai Corporation, in a public–private partnership with Srinivas Solid Waste Management Services Pvt. Ltd., established a 100 TPD capacity bio-CNG plant in Chetpet, Chennai. With a capital cost of INR 280 million and operating costs of nearly INR 4.5 million per month — mainly for raw materials and manual waste segregation — the project achieved a return on investment within seven years of startup.

The plant receives 110 TPD of waste, of which 10 tonnes is material that is rejected and sent to the dumpsite. The facility collects waste from the BWGs in Chennai for a fee, using its own vehicle fleet. Due to poor segregation of organic waste at the source, the facility employs workers to manually segregate the organic waste at the Chetpet facility.

The 100 TPD plant, which operates at full capacity, produces a total of 12,000 m^3 of raw biogas daily that is further purified to ~95% natural gas and compressed for distribution. Of the 4,800 kg of CNG produced daily, 2,500 kg is supplied to Gas Authority of India Ltd. for distribution to the city, and the rest is sold to the retail market (e.g., restaurants) at a 10% discount relative to the liquid petroleum gas market rate, to incentivise customers. The digestate from the plant is dried and given away to farmers in Chengalpattu and Tiruvannamalai.[32]

Exhibit 9 The Bio-CNG Plant in Chetpet, Chennai

Source: Citizen Matters, https://chennai.citizenmatters.in/chennai-waste-management-segregation-bio-cng-plants-coc-66998

Case Study: Incentivising Market Demand for Compost in Rio de Janeiro

In Rio de Janeiro, waste management services are provided by the municipal public company Companhia Municipal de Limpeza Urbana (COMLURB). The city has a biomethanation plant that converts 70 TPD of waste into 10 TPD of compost. The organic waste feedstock is converted to biogas and the digestate byproduct is further processed using open-windrow composting followed by screening in a rotary trommel.

Ninety-five percent of the compost is used for municipal afforestation projects and the remaining 5% is sold at a low price of around US$8/ton, to stimulate demand.[33]

Several other factors contribute to the successful sale of compost to farms. An on-site research centre that tests compost for quality, heavy metals, and compliance with national standards contributes to promoting product uptake among farmers. The marketing and promotion of the compost by COMLURB, and the opportunity to get the compost tested and trialled, enticed the initially sceptical farmers to use compost produced from MSW. The demand for compost also grew after farmers achieved high-quality results on their farms, leading them to expand their use of compost from growing coffee and citrus fruit to include vegetable production.

Case Study: Evaluating the Resource Potential and Emissions Reduction Potential from Organic Waste Diversion in Lucknow

Existing waste management practices in Lucknow underscore an untapped opportunity to divert organic waste from the city's dumpsite. With a per capita MSW generation rate of 0.44 kg/day, Lucknow produces about 730,000 tonnes of waste annually, close to half of which is biodegradable.[34] Increasing composting and AD can reduce the amount of waste sent to Shivari dumpsite and provide sizeable climate benefits. By-products can also serve beneficial uses.

This analysis summarises the current situation in Lucknow (baseline scenario) and three alternative management scenarios in which organic waste is diverted. It quantifies the resulting climate benefits of each scenario using tools developed by the US Environmental Protection Agency, including the Solid Waste Emissions Estimation Tool (SWEET), OrganEcs, and the AD Screening Tool.

Baseline Scenario

Of the total waste generated in Lucknow, 60% is currently collected; 21% of the collected waste is sent to recycling facilities and 2% is composted, while the remainder is sent to the dumpsite.[35] This highlights an untapped potential of organic waste diversion.

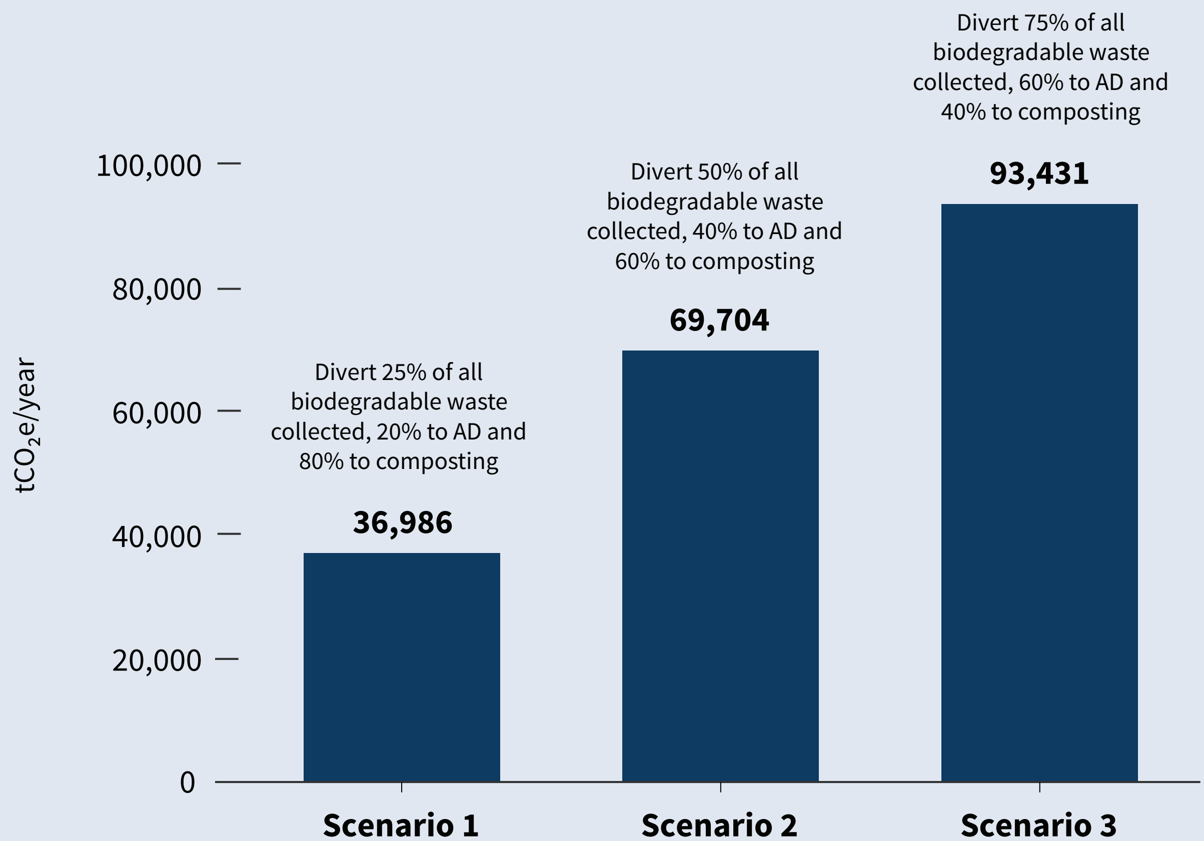
Alternative Scenarios

The three alternative scenarios (see Exhibit 10) build on the baseline by diverting increasing amounts of biodegradable waste to composting and AD facilities based on LMC's proposed action plans, which include installation of a bio-CNG plant and expanding centralised and decentralised composting.[36] In this study, a 3% average annual growth rate for amount of waste collected is assumed to account for growth in population, waste generation, and collection rate and alternative scenarios start in 2025.[37] The three waste diversion scenarios modelled in this study entail diverting 25%, 50%, and 75% of organic waste from the dumpsite.

Comparing the modelled results of the three alternative scenarios between 2025 and 2050 reveals significant GHG emissions reduction potential in all scenarios. Increasing biodegradable waste diversion from the baseline scenario to 25%, with 20% of the diverted waste sent to anaerobic digesters and the rest to composting facilities, could reduce GHG emissions by about 40,000 tonnes per year of CO_2 equivalent (tCO_2e/year) compared with the baseline. This emissions reduction potential is equivalent to removing more than 8,200 gasoline-powered passenger cars from the road for a year.[38] Increasing biodegradable waste diversion to 50% with a split between AD (40%) and composting (60%) could reduce GHG emissions by about 70,000 tCO_2e/year. Increasing biodegradable waste diversion to 75% with a 60:40 ratio between AD and composting could reduce GHG emissions by more than 93,000 tCO_2e/year.

There is also potential to harness biogas generated from the planned bio-CNG plant in Lucknow for beneficial end uses such as power generation. Alternative Scenario 1, where 20% of the diverted biodegradable waste is sent to an AD facility, could generate an additional 1.8 million cubic metres (m^3) of biogas annually — enough to support gas cooking for almost 3,000 families of six or generate 6,110 megawatt hours (MWh) of electricity per year, which could power about 340 50-m^3 cold storage units.[39] Assuming the planned 300 TPD bio-CNG plant will be able to operate at 90% capacity and process 60% of diverted biodegradable waste, as modelled in Alternative Scenario 3, it could generate more than 17.6 million m^3 of biogas per year, which is enough to support gas cooking for about 27,000 families of six. If used for electricity generation, it could generate more than 57,000 MWh of electricity per year, which could power more than 3,100 50-m^3 cold storage units.

Exhibit 10 Greenhouse gas emissions reduction potential for modelled alternative scenarios



RMI Graphic. Source: RMI analysis

Exhibit 11 Stakeholder roles and responsibilities, waste recovery and treatment

Stakeholder Group	Roles and Responsibilities
BWGs	• Undertake on-site treatment of organic waste.
LMC, waste treatment operators, and project developers	• Conduct feasibility assessments to evaluate organics processing capacity requirements, project viability, and investment needs and seek funding where necessary. • Develop composting and biogas facilities. • Implement capacity building and awareness programmes to develop local technical capacity of key waste management personnel.

RMI Graphic. Source: RMI analysis

Waste Disposal

When organic waste is disposed of at landfills and dumpsites, it generates LFG as it decomposes. Uncontrolled release of the LFG emissions, which primarily contain CO_2 and methane, contributes to global warming. To reduce the release of LFG, the organic waste should be diverted from these disposal sites. However, several studies have shown organic waste may still end up at disposal sites despite source separation programmes.[40] Moreover, biodegradable waste already in landfills and dumpsites will continue to emit LFG for several years unless the gas is captured. The following strategies explore opportunities to capture and control LFG, to harness this gas as a valuable energy resource, and to reduce GHG emissions in the waste sector (see Exhibit 13).

1. Minimise the Surface Area of the Active Working Face

Minimising the exposed surface area of the daily active working face — i.e., where waste is actively being received — can limit the migration of LFG to the surface. However, for dumpsites like Shivari that are completely exposed, minimising the surface area of the active working face should be complemented with applying daily covers at the non-working face — i.e., areas of the dumpsite not actively receiving waste — to limit LFG escaping into the atmosphere.

2. Install Landfill Covers

Landfill covers are materials placed over the disposed waste to mitigate odours and disease vectors, deter scavenging, and minimise water infiltration. They also reduce the exposed surface area of the waste mass, limiting the migration of LFG emissions from the underlying waste to the surface and enhance the overall stability of the disposal site. Landfill cover types include daily, intermediate, and final cover. Materials like soil, green waste, compost, or shredded tires are commonly employed as daily cover for landfills. For prolonged periods of inactivity at the disposal site (e.g., 6 months), interim covers made of compacted earthen material are recommended, while final covers are recommended for inactive sites or sections of the landfill or dumpsite that no longer receive waste.[41]

3. Use Biocovers to Oxidise Methane

A biocover is a layer of organic material used to cover areas of a landfill to reduce emissions. Biocovers are affordable and easy to implement and reduce the release of methane by converting it into carbon dioxide, a less potent GHG.[42] However, they should not be considered a replacement of gas collection and control systems (GCCS), which are more effective at capturing LFG emissions. Organic materials like compost, yard waste, and dewatered sewage sludge can serve as biocover materials, providing alternative end uses and options for biodegradable waste.[43]

4. Install Gas Collection and Control Systems

The SWM Rules, 2016 require the installation of LFG control systems at landfill sites. While a lack of legislation on LFG recovery and its utilisation prevent the wide-spread implementation of this technology in India, notable examples of such projects include a LFG-to-energy system installed at Gorai Landfill in Mumbai and India's largest LFG-to-bio-CNG plant in Hyderabad.[44] Gas capture systems are essential to reduce LFG emissions. This gas can be collected through a well and pipeline system and can be used to generate electricity, heat, or steam, or it can be destroyed through flaring. Although gas capture systems are typically installed at landfills, they can also be installed at dumpsites like Shivari. However, installing these systems requires other operational improvements at the dumpsite such as installing landfill covers and limiting waste pickers' access to avoid damaging the gas capture systems and minimise fire hazards from oxygen intrusion.

Case Study: São Paulo's Landfill Gas-to-Energy Project

In 2007, the municipality of São Paulo commissioned Biogás, a private company specialising in LFG recovery, to develop the Bandeirantes Landfill Gas to Energy Project. The Bandeirantes project is the largest LFG recovery plant in the world (see Exhibit 12), generating 170,000 MWh of electricity annually. The landfill, located in the São Paulo metro area, was receiving nearly half of the city's approximately 15,000 TPD of waste until 2007, when it was decommissioned. The site was remediated, covered, and planted over with grass.[45]

The São Paulo municipality initiated the project through the United Nations Framework Convention on Climate Change Clean Development Mechanism (CDM) to procure funding. Biogás took responsibility for the project's costs and risks as well as the legal procedures for the CDM approval, which was a four-year-long process. Development of the LFG-to-electricity plant began in June 2007 and the plant became operational in 2008. LFG was combusted in the plant through 16 engines, with a total electricity production capacity of 22.4 megawatts. Gas yield was continuously monitored to evaluate future flow rates, and the system was predicted to capture LFG until 2018, after which the gas would be insufficient for operations.

Exhibit 12 **The Bandeirantes landfill gas-to-energy plant in São Paulo, Brazil**

Source: WtERT, **https://www.wtert.net/paper/3819/Current-State-of-Waste-Management-in-Brazil.html**

The municipality raised more than €13 million in 2007 for selling certified emissions reductions as per the Brazilian legislation and applicable international rules governing the CDM. These funds were used for environmental improvements in the communities surrounding the landfill. The plant provided various environmental, social, and economic benefits, including abating GHG emissions, creating employment opportunities, enabling investments in recycling, and educational awareness projects.[46]

Exhibit 13 Stakeholder roles and responsibilities, waste disposal

Stakeholder Group	Roles and Responsibilities
LMC and waste service providers	• Evaluate the technical and financial requirements for facility upgrades and secure financing, if needed. • Implement dumpsite upgrades (e.g., install covers and GCCS to minimize fugitive emissions).
Technology providers, nongovernmental organizations (NGOs), engineering/consulting firms, and academic institutions	• Offer training and technical support to waste management personnel for effective operation and maintenance of landfill covers, gas capture systems, or other technology deployed at the disposal site.

RMI Graphic. Source: RMI analysis

Crosscutting Components

For a holistic systems approach to managing organic waste, this section explores a set of strategies that cut across the MSW value chain. These strategies include opportunities to improve the policy and regulatory framework, data transparency, access to finance, and stakeholder awareness and capacity building.

Policy and Regulatory Framework

Leveraging policy and regulatory instruments is essential to preventing waste, prioritising the reuse and recycling of waste, and harnessing resources through material recovery. In the absence of these instruments, implementing sustainable organic waste is voluntary, and thus, insufficient to ensure wide-scale deployment of organic waste management solutions. A supportive policy environment also bolsters investor confidence and thus helps facilitate private sector investment necessary to scale technology deployment (see Exhibit 15).

1. Enhancing Regulatory Compliance Through Monitoring and Reporting

In spite of India's comprehensive regulatory framework on solid waste management, implementation in Lucknow is inadequate due to insufficient infrastructure, lack of awareness and training among workers, financial constraints, and a lack of accountability among stakeholders, among other factors. For example, although institutional generators, market associations, hotels, and restaurants are mandated by the SWM Rules, 2016 to segregate their wet waste, compliance is often lacking. Adhering to these rules will require regular monitoring, reporting, and review of the rules against key performance indicators, which could include periodic inspections and audits as well as enforcing fines and penalties. ULBs can also play a crucial role in improving compliance by notifying relevant stakeholders of bylaws and fines, and providing a clear definition for each type of violation.[47] The government of Uttar Pradesh has released a draft "Municipal Solid Waste (Management & Handling) and Sanitation Guidelines" for ULBs in the state. These guidelines are complementary to the national SWM Rules, 2016 as they are further tailored to the municipalities to promote implementation and compliance.

2. Introduction of Landfill Taxes and Pay-as-You-Throw Programmes

Imposing a tax on landfill operators based on the volume of waste received can improve source reduction and waste diversion. Because these costs are eventually transferred to waste generators as higher collection fees, landfill taxes can be an effective policy mechanism to encourage reduction of waste and/or segregation of biodegradable waste at the source, lowering the amount of residual waste sent to final disposal sites. Revenue from landfill taxes can be used on projects to divert organics and sustainable waste management. In the UK, from 2001 to 2009, 750 landfill sites closed — a change attributed to the gradual increase in landfill tax from £8/tonne to £80/tonne in that period.[48]

Another similar approach to prevent and minimise waste at landfills can be employed at the source, where waste generators pay a volume-based fee for waste disposal, as opposed to a flat fee. These types of pay-as-you-throw (PAYT) payment structures incentivise reducing waste generation and can at the same time promote diversion practices like composting and recycling.[49] Both landfill tax and PAYT schemes promote waste recovery and reduce the amount of waste sent to disposal sites. Communities that implement unit-based PAYT pricing generally see a decrease in overall waste generation.[50]

3. Integrate the Informal Sector

The informal sector plays a crucial role in the recovery of recyclable materials across India. The SWM Rules, 2016 emphasise the recognition of the informal sector's crucial contribution and its integration into the formal sector. However, despite national and state-level policies that highlight the importance of integrating the informal sector into the formal waste management framework, implementation remains inadequate due to a lack of specific rules and mandates for their formal employment.

Participation of the informal sector, often called waste pickers, at primary and secondary collection points and at dumpsites can help ULBs address gaps in waste segregation, collection, or disposal. Nevertheless, the work of waste pickers is insecure, carried out in unsafe conditions, and comes with a social stigma.[51] Integrating these informal sector workers into the formal waste management framework will not only enhance material recovery and improve data tracking, but also provide safer working conditions, improve wages, and enhance their livelihoods.[52]

Case Study: Integrating the Informal Sector to Promote Material Recovery in Pune, India

Pune is the second largest metropolis in Maharashtra, governed by the Pune Municipal Corporation (PMC). With a population of 3.1 million, the city generates around 1,500–1,600 tonnes of waste daily. Of this total, about 85% is treated and the remainder goes to the landfill. Before 2008, the municipal waste collection system in the city involved residents disposing of waste in community bins and the informal sector scavenging through these containers to retrieve recyclables for sale.[53]

In 2008, a partnership between PMC and informal waste workers created SWaCH, an institution to formally integrate waste pickers in the waste management system as door-to-door waste collectors. The pilot programme enabled 1,500 waste pickers to provide collection services for 125,000 households in select wards across Pune. Presently, over 2,700 waste pickers have been integrated into the formal system through SWaCH (see Exhibit 14). This model does not require the municipality to pay waste pickers; instead, waste generators pay SWaCH directly for waste collection. The SWaCH waste pickers collect waste door-to-door, segregate the recyclable material, and dispose of the remaining waste at designated sites in the secondary waste collection system. PMC encouraged decentralised waste management by providing a 5% rebate on property tax to institutions, housing societies, and commercial establishments that compost on-site. SWaCH is authorised by PMC to enter into private service contracts with institutions, housing societies, and commercial establishments for waste collection, on-site processing, and facility management services.[54]

Exhibit 14 **SWaCH cooperative waste pickers in Pune**

Source: NIUA, https://smartnet.niua.org/sites/default/files/resources/towards_an_inclusive_swachh_bharat-integrating_informal_sector_recyclers.pdf

4. Enhanced Stakeholder Collaboration

Effective waste management requires a cohesive and integrated approach, yet municipal authorities, waste generators, collection agencies, recycling facilities, and disposal sites frequently operate in silos, leading to inefficiencies and redundancies. Additionally, crucial data and insights often remain isolated within different stakeholder groups. Establishing a task force that brings together diverse stakeholders can foster coordination, communication, and collaboration.

Exhibit 15 Stakeholder roles and responsibilities, policy and regulatory framework

Stakeholder Group	Roles and Responsibilities
Central Government (Ministry of Environment, Forests and Climate Change, Ministry of Urban Development, Central Pollution Control Board)**,** **State Government of Uttar Pradesh** (State Pollution Control Board and LMC)	• Conduct regular monitoring, reporting, and review of waste management rules against key performance indicators to assess the need for updates. • Update or establish new rules to address policy gaps as needed (e.g., incorporate landfill taxes, integrate the informal sector, develop procurement standards for organic waste-derived products). • Monitor and enforce rules to ensure compliance through periodic inspections and audits, enforcing fines and penalties, awareness programs, and exploring other compliance mechanisms.
LMC and waste service providers	• Comply and adhere to rules. • Establish a task force that oversees these waste management activities and promotes coordination among key stakeholders. • Conduct public outreach to improve awareness of policies and regulations. • Collaborate with and integrate informal workers into the waste management processes through local policies and bylaws.

RMI Graphic. Source: RMI analysis

Data Transparency

Unrecovered organic waste decomposes in dumpsites and landfills and generates LFG. Access to reliable and accurate waste and emissions data can enable better assessment and management of the climate impact of these gases by improving data transparency, highlighting priority intervention areas, informing policy interventions and strategic solutions, and tracking the progress of solutions deployed (see Exhibit 16).

1. Collect Robust Waste Sector Data

Insufficient data on waste generation, waste composition, and waste flow makes it difficult to plan and design waste management interventions. For example, facility planners and designers may struggle to determine the appropriate capacity and effectively design systems and technologies needed to manage and scale organic waste treatment solutions.[55]

Collecting robust waste sector data enables emissions monitoring, identifying priority areas of intervention, designing context-specific local waste management solutions, and planning operational details like number of vehicles, route management, and waste collection tracking. In addition, it is important to conduct regular waste characterisation studies to assess the composition of the waste streams and design targeted interventions for specific constituencies. Data management can aid in carrying out feasibility studies, selecting viable technology solutions, enabling procurement of a constant and clean feedstock, and in overall planning efforts.[56]

2. Make Waste and Emissions Data Publicly Available

Making waste and emissions data publicly available makes it possible for various parties to evaluate the hard and soft infrastructure needed to improve the waste management system. Transparency promotes accountability and shared learnings across all stakeholder groups and levels of decision-making, which can facilitate dialogue around waste management, especially related to diversion and resource recovery measures, and broadly improves the system's progress.

Exhibit 16 Stakeholder roles and responsibilities, data transparency

Stakeholder Group	Roles and Responsibilities
Central Government (Central Pollution Control Board)**,** **State Government** (State Pollution Control Board)**,** **LMC, and waste service providers**	• Conduct baseline survey and waste characterisation studies; prepare and/or update the city's waste inventory. • Develop and maintain a repository of waste-related data and make it publicly available via online platforms.
NGOs, academic institutions, and think tanks	• Collaborate with municipal authorities and waste management agencies to conduct waste characterisation studies. • Collaborate with relevant agencies to provide input on improving data access and accuracy.

RMI Graphic. Source: RMI analysis

Finance

The difficulty of securing funding for developing essential infrastructure for waste collection, recycling, and treatment, and for converting dumpsites to sanitary landfills is one of the most significant barriers to advancing sustainable waste management. Many factors contribute to this challenge, including the high cost of infrastructure, nonbankable projects, limited technical capacity, lack of awareness of funding sources, high interest rates, and limited available financing for waste management projects. Furthermore, ongoing operational and maintenance costs of waste management projects can strain limited budgets. ULBs, in particular, struggle to allocate funds for regular waste collection, treatment, and disposal. These funding constraints can stifle the adoption of environmentally friendly waste management technologies and practices.

1. Provide Affordable Finance through Subsidies, Grants, and Concessional Financing

One way to fund waste management systems is to provide municipalities and waste service companies low-interest concessional financing, allowing them to avoid higher rates on commercial loans. Grants and subsidies, which require no repayment, can also help lower the barrier to entry for new players, mobilise private sector investment, and enable deployment of technology solutions. Development finance institutions and philanthropic foundations can play a role in providing low-interest financing and grant funding. The government can also improve access to finance by providing subsidies and tax credits, particularly in nascent markets and conducting investment training programmes that raise awareness of available funding opportunities and ways to secure such funding.

2. Access Project Preparation Facilities

Accessing debt or private sector financing for urban infrastructure projects is often difficult because many projects are not bankable. Project preparation facilities (PPFs) can prepare projects for investment and unlock private sector finance by helping bridge gaps through financial and technical support such as conducting market research and feasibility assessments. PPFs can also help municipalities with limited capacity to complete funding applications to enable project implementation, address knowledge gaps, and identify, scope, and prioritise projects.[57]

3. Reduce the Cost of Finance through Risk-Sharing Mechanisms such as Blended Finance

High-risk projects cost more to finance to compensate investors for their risk exposure. In emerging economies, waste management projects often do not have the same access to risk mitigation tools that are standard in more developed markets. Risk-sharing mechanisms like blended financing can lower the cost of finance by spreading the risk across various funding sources including private, public, philanthropic, concessional, or institutional investors.[58] This approach leverages the different risk tolerance levels of investors to catalyse private sector investment.

4. Guarantee Revenue through Procurement Contracts and Offtake Agreements

Procurement contracts and offtake agreements can guarantee a steady revenue for municipalities and waste management companies. Such binding agreements can reduce the burden on service providers to recover costs while providing a guarantee of product and revenue for the buyer and seller, respectively. This not only lowers the risk of not recovering costs, but also improves the viability of organics-derived product markets.

5. Improve Cost Recovery through Service Offering Expansion and Innovative Tariff Structures

Demonstrating an ability to recover costs is important to financial institutions when evaluating projects for funding. Municipalities may find it difficult to secure affordable financing for waste management in part because user fees do not cover operating costs and may be difficult to collect due to the unwillingness or inability of waste generators to pay. LMC and other waste service providers can improve cost recovery by expanding services to include organic waste treatment, selling end products like compost, biogas, and digestate, or developing LFG-to-energy projects.[59]

To help address a customer's inability and/or unwillingness to pay and improve cost recovery, waste management providers can explore different tariff structures, such as imposing higher fees in high-income communities to subsidise low-income communities. PAYT models can also reduce the volume of waste to be handled, in turn reducing operating costs and improving project viability. Service providers can consider incorporating user charges into other utility bills such as electricity or water that have higher payment collection success rates to improve cost recovery. Several countries in Latin America and the Caribbean such as Colombia, Ecuador, and Venezuela recover solid waste management costs using this method.[60]

Case Study: Composting of Market Waste with a Joint Venture Company in Bangladesh

Dhaka city in Bangladesh has a population of nearly 16 million and generates 5,000 TPD of waste. The Dhaka City Corporation is responsible for managing waste in the city, along with Waste Concern, a private agency.

Waste Concern collaborated with the Dutch company World Wide Recycling (WWR) to develop plans for a 700 TPD composting facility. WWR successfully registered the project through the United Nations-run clean development mechanism in 2008. However, the collapse of the carbon market in 2012 resulted in insufficient funding for the originally proposed project, so instead, one plant of 130 TPD capacity was installed in Bulta, Narayanganj.

The total investment cost of this joint venture facility between Waste Concern and WWR Bio Fertilizer Ltd. Bangladesh was US$3.6 million. The project was financed through a combination of grants, equity, loans, and carbon credits:

- A €500,000 grant from International Business and Cooperation of the Dutch Ministry of Economic Affairs.
- Three equity investments from WWR, the Entrepreneurial Development Bank of the Netherlands, and High Tide Investment, a Dutch investment firm.
- A soft loan from High Tide Investment.
- A conventional loan from Dutch Bangla Bank of Bangladesh.[61]

The compost was sold to a fertiliser company at $79/tonne, which included a 25% markup from the cost of production; the fertiliser company subsequently sold the compost to farmers at a higher price through its established distribution network. This model leverages foreign direct investment through a joint venture and an established distribution network with the country's largest synthetic fertiliser distributor to unlock a compost market.[62]

Exhibit 17 Community-based MSW management in Bangledesh

Source: Waste Concern, https://www.env.go.jp/recycle/3r/en/asia/02_03-3/06.pdf

Exhibit 18 Stakeholder roles and responsibilities, finance

Stakeholder Group	Roles and Responsibilities
Investment community (development finance institutions, multilateral banks, green banks, and philanthropic foundations)	• Provide grants, concessional loans, and loan guarantees to municipalities and waste service providers to support the development and scaling of organic waste management solutions.
Central Government (Ministry of New and Renewable Energy) **and State Government**	• Provide subsidies, tax credits, and other financial incentives for proven organic waste management and gas capture technologies. • Facilitate partnerships between private sector players and financial institutions that can provide funding. • Facilitate investment training programmes for technology providers and waste management officials.
LMC and waste service providers	• Access PPFs for project support and to evaluate project readiness for investment. • Identify additional opportunities for revenue generation (e.g., through organics recycling, the sale of waste-derived products, and exploring different tariff structures to improve cost recovery).
Multilateral organizations, development agencies, and NGOs	• Develop PPFs for waste projects and work with municipal authority to evaluate projects to assess investment readiness.

RMI Graphic. Source: RMI analysis

Stakeholder Awareness and Capacity Building

Educational awareness and capacity-building initiatives can help drive changes in behaviour and perspectives towards waste management and develop the acumen to adopt innovative technologies and practices. Further, building technical capacity among waste management personnel can help overcome the barriers of technical feasibility, unlock project finance, and improve the long-term sustainability of projects (see Exhibit 19).

1. Develop Technical Capacity among Key Waste Management Officials, Regulators, and Policymakers

Limited technical expertise often limits project viability and long-term sustainability of projects. Identifying knowledge gaps among key personnel ensures that capacity-building efforts are effectively tailored to address these gaps. Developing local technical capacity among waste management officials, regulators, and policymakers will reduce operational downtimes, lower operations and maintenance costs, improve return on investment, and promote the adoption of favourable policies. Collaborating with educational institutions, waste management organisations, and international experts to develop training programmes, exchange programmes, and facility tours can help close this knowledge gap and facilitate project implementation.[63] Targeted trainings may include sustainable waste management practices like organics recycling, leachate and LFG management, landfill design and operation, landfill mining, waste economics, and investment training programmes.

2. Implement Educational Awareness and Outreach Programmes

Educational awareness initiatives can foster a sense of ownership and secure buy-in from stakeholders, whether they are waste generators, waste haulers, facility operators, ULBs, or regulators and policymakers. Awareness campaigns may, for instance, be aimed at waste generators to improve source segregation, at waste haulers to keep organic waste separated during the hauling process, at end-users to educate them on benefits of compost, or at project developers to foster awareness of funding opportunities. Further, these educational programs should help the audience understand the underlying motivation behind such initiatives.

The content of these programmes as well as the delivery format should be tailored to the audience. For example, social media campaigns may be leveraged to reach college students and young adults, while radio jingles might be better suited to a food or vegetable vendor at the market. Exploring multiple platforms and local languages can ensure widespread dissemination and impact. Other delivery formats may include flyers, workshops, television ads, university curriculums, and exchange programmes. Additionally, leveraging authority figures or people with significant reach such as community leaders and influencers can promote the success of these programmes.

Exhibit 19 Stakeholder roles and responsibilities, stakeholder awareness and capacity building

Stakeholder Group	Roles and Responsibilities
LMC	• Identify knowledge gaps among waste management officials and collaborate with experts to develop and deliver targeted training programmes.
Think tanks, academia, and NGOs	• Facilitate educational exchange programmes, workshops, and seminars, and share waste management best practices to develop local capacity and improve awareness.
Public sector, private sector, civil society, and impacted communities	• Attend and participate in educational awareness and outreach programmes to improve understanding. • Implement lessons learned to promote best management practices (e.g., effectively segregate organic waste, practise home composting).

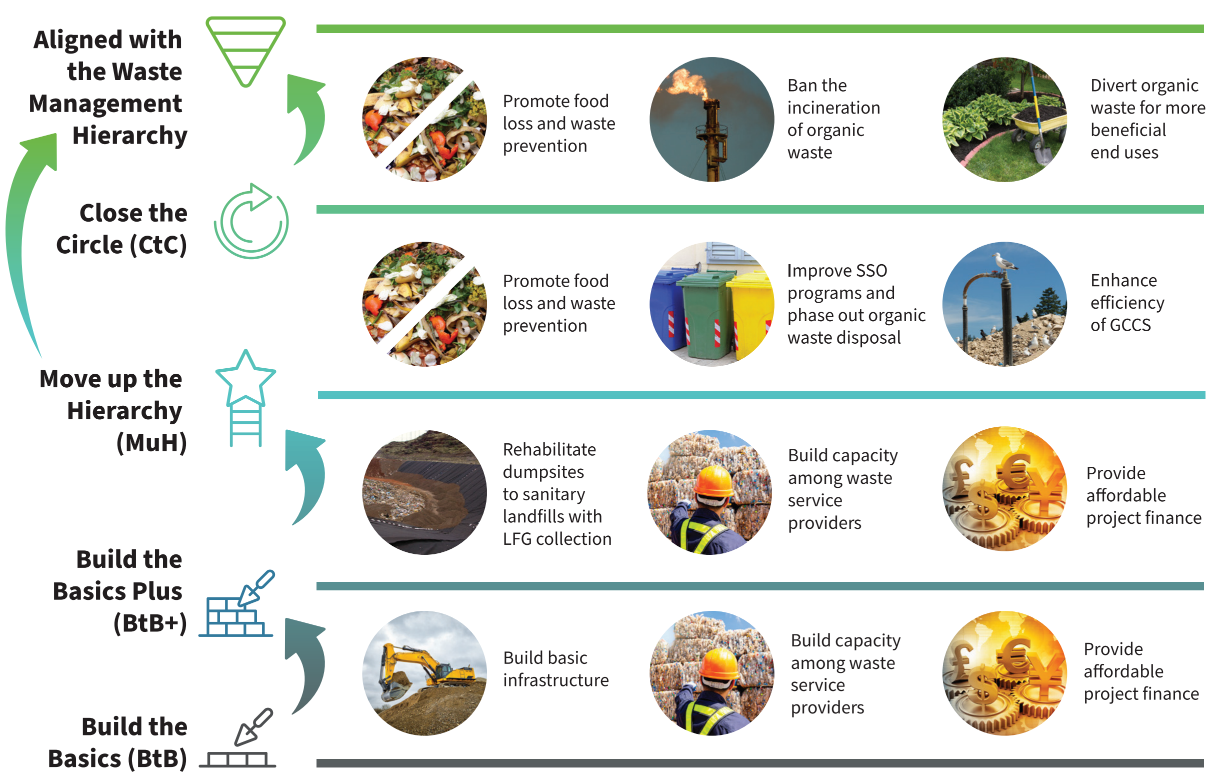
RMI Graphic. Source: RMI analysis

4. Conclusion and Recommendations

A growing population and rising waste generation demand solutions that reduce reliance on disposal sites. Today, material recovery efforts are often limited to dry recyclables like plastics, glass, paper, and metal. However, biodegradable materials like food and yard waste present an untapped opportunity. Expanding material recovery efforts to include biodegradable waste promotes public health and safety and provides climate benefits in addition to reducing reliance on unsustainable systems like landfills and dumpsites. Further, these resource recovery measures offer economic development opportunities through end products like compost and biogas.

This playbook leverages the pathways outlined for the BtB+ archetype in RMI's recently published report, *A Playbook for Municipal Solid Waste Methane Mitigation: Recommendations Based on Global Waste Management Archetypes*, to recommend organic waste management strategies that reflect the current waste management situation in Lucknow, the largest city in India's most populous state. These strategies span the MSW management value chain, including waste generation, collection and transport, recovery and treatment, and final disposal. The playbook also explores strategies to promote an enabling policy environment, improve access to affordable finance, improve data transparency, and develop local technical capacity and awareness.

Exhibit 20: Key levers for progressing across MSW management archetypes



RMI Graphic. Source: RMI analysis

The authors recommend three key levers for the BtB+ archetype, namely, rehabilitating dumpsites into sanitary landfills with LFG collection, developing technical capacity among waste service providers, and providing affordable finance for organic waste management projects (see Exhibit 4), to better align its waste management practices with the waste hierarchy.

Despite India's robust 2016 SWM Rules, implementation is slow. Accordingly, Lucknow should continue the bioremediation of legacy waste at the Shivari dumpsite and consider upgrading the dumpsite to a sanitary landfill. Importantly, the landfill should be fitted with GCCS to capture LFG for beneficial end use. At the same time, the city can deploy small-scale composting and AD systems that require lower investment capital to treat organic waste and divert them from the dumpsite. This will facilitate the recovery of organic waste for conversion to beneficial end products, despite funding constraints. However, adequate enforcement measures through fines, penalties, and educational awareness programmes, among others, are needed to promote compliance and improve organics recycling and LFG capture at the disposal site.

Finally, building technical capacity among waste service providers and access to affordable financing are critical to accelerate large-scale deployment of infrastructure to collect and treat recovered organic waste and to capture LFG emissions from nondiverted decomposed biodegradable waste.

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RMI Innovation Center
22830 Two Rivers Road
Basalt, CO 81621

www.rmi.org