Summary for Decision Makers

A Playbook for Municipal Solid Waste Methane Mitigation

Recommendations Based on Global Waste Management Archetypes

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About RMI

RMI is an independent nonprofit, founded in 1982 as Rocky Mountain Institute, that transforms global energy systems through market-driven solutions to align with a 1.5°C future and secure a clean, prosperous, zero-carbon future for all. We work in the world's most critical geographies and engage businesses, policymakers, communities, and nongovernmental organizations to identify and scale energy system interventions that will cut greenhouse gas emissions at least 50 percent by 2030. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; and Beijing.

About WasteMAP

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 sub-national 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.

About GMH

The Global Methane Hub organizes the field of philanthropists, experts, nonprofits, and government organizations to ensure we unite around a strategy to maximize methane reductions. We have raised over $200 million in pooled funds from more than 20 of the largest climate philanthropies to accelerate methane mitigation across the globe. Visit **www.globalmethanehub.org** to learn more about organizations that supported the commitment.

Contents

Preface

The waste sector contributes to about 20% of anthropogenic methane emissions globally.[1] Reducing methane emissions from the waste sector is critical to limiting global warming in the near term. The purpose of this playbook is to provide key decision makers at the national, subnational, and local levels with a guide on strategies to reduce methane emissions from municipal solid waste (MSW).

Because waste management practices vary widely across the globe, this playbook first identifies four MSW management categories or "archetypes" based on similarities in how various countries and regions currently manage their waste. The playbook then develops strategies to mitigate methane for each archetype, providing a starting point for countries to further customize methane abatement solutions unique to their local context.

Reducing Waste Sector Methane Emissions: An Untapped Opportunity

Rapid population growth, economic development, and increasing consumption underscore the need for more sustainable waste management solutions. In 2020, global waste generated was estimated at 2.24 billion metric tons and is projected to reach 3.88 billion metric tons by 2050.[2] Unless more sustainable waste management practices — such as source reduction and waste diversion — that reduce reliance on disposal sites are implemented, most of this waste will continue to be sent to landfills and dumpsites, many of which are approaching their maximum capacity.

Unsustainable waste management not only has public health and safety implications such as groundwater contamination, pests, and diseases, it also has adverse climate impacts. As more waste is generated and sent to disposal sites, methane emissions from the decomposed organic waste fraction will continue to increase unless the waste is prevented from being generated, is diverted, or the methane from decomposed waste is captured.

Methane is a potent greenhouse gas that is responsible for about 30% of global warming since preindustrial times and has about 80 times the warming impact of carbon dioxide over a 20-year time frame.[3] Methane emissions from MSW are estimated to increase by 13 million metric tons per year over the next decade alone, which is equivalent to greenhouse gas (GHG) emissions from 278 coal-fired powerplants operating for a year.[4] Bold commitments like the Global Methane Pledge, which aims to reduce global methane emissions across high-emitting sectors (like the waste sector) by at least 30% of 2020 levels by 2030, are necessary to limit global warming to 1.5°C above preindustrial levels.[5]

> **“As more waste is generated and sent to disposal sites, methane emissions from the decomposed organic waste fraction will continue to increase unless the waste is prevented from being generated, is diverted, or the methane from decomposed waste is captured.”**

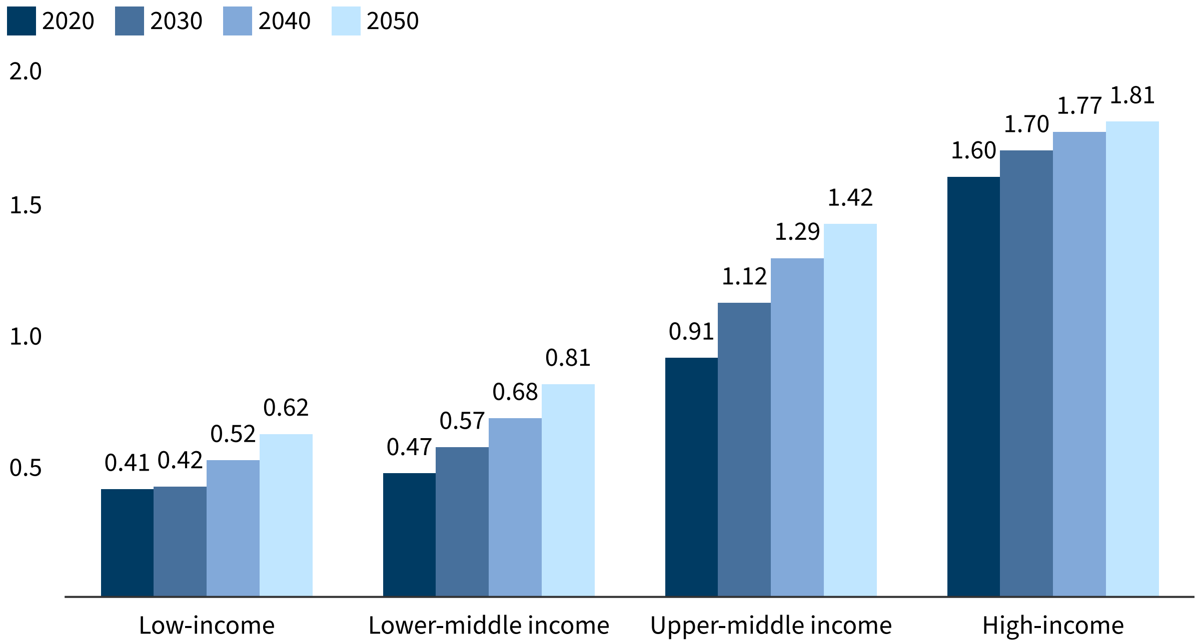
Recent advancements in remote sensing technologies, mainly satellite and aircraft observations, have also brought more attention to the waste sector's contribution to this short-lived climate pollutant. For example, a study by the Netherlands Institute for Space Research found that in Lahore, Pakistan, methane emissions from landfills amount to more than 19 metric tons per hour.[6] This would be equivalent to GHG emissions from 1 million gasoline-powered passenger cars driven for a year.[7] According to the study, methane emissions in Lahore estimated using satellite observations are twice as high as those recorded in city inventories.[8] These observations highlight near-term and long-term methane abatement opportunities for the waste sector.

Waste management practices — including waste generation, collection, treatment, and final disposal — vary widely across the globe because of the level of economic development, regulatory framework, available financing, and geographic factors such as cultural norms and land availability. For example, according to the

World Bank's *More Growth, Less Garbage* report,[9] in 2020, high-income countries were estimated to generate about four times as much waste as low-income countries on a per capita basis, and waste generation will continue to increase significantly across the globe over the next three decades (see Exhibit 1).[i]

Exhibit 1 **Projected global waste generation by income group**

Kilograms per capita per day



RMI graphic. Source: The World Bank, https://openknowledge.worldbank.org/bitstreams/b8714e79-1b2e-5c9f-9ea5-326072cf39da/download

At the same time, food and yard waste make up the single largest share of the MSW stream regardless of income level. This can range from 32% in high-income countries to 56% in low-income countries, highlighting significant opportunities to divert this waste from disposal sites.[10] In terms of collection, many high-income countries have achieved universal waste collection, whereas low- and lower-middle income countries may collect less than half of waste currently generated due to limited infrastructure and financing.[11] Regional differences also exist in the technologies deployed to manage waste, such as the use of composting, anerobic digestion, waste-to-energy (WTE) facilities, or sanitary landfills.

Based on these characteristics, this report identifies four MSW management archetypes and explores strategies to reduce methane emissions for each archetype. By tailoring methane abatement solutions to different archetypes, the authors acknowledge the unique differences in waste management practices around the world and underscore that the strategies to reduce methane must reflect these differences.

Although source reduction (i.e., preventing waste from being generated) is the best and preferred option to reduce methane emissions from solid waste, this playbook focuses on methane mitigation strategies after the waste has been generated.

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i This report refers to the following definitions by the World Bank to discuss the world's economies (in 2015 USD/capita/year): low income = $1,025 or less; lower middle income = $1,026–$4,035; upper middle income= $4,036–$12,475; and high income = $12,476 or more.

Municipal Solid Waste Management Archetypes: A Methane Emissions Perspective

This section develops archetypes that characterize global MSW management practices, underlining that although waste management practices may vary vastly between countries and regions, many countries exhibit similar characteristics in their approaches to managing waste.

These archetypes are based on four main building blocks: (1) source reduction; (2) waste diversion; (3) waste disposal; and (4) a cross-cutting component that explores policy and regulatory framework, emissions transparency, finance, and stakeholder awareness and capacity building. The building blocks inform several guiding questions that allow the authors to evaluate waste management practices globally and group them into four archetypes, Build the Basics (BtB), Build the Basics Plus (BtB+), Move up the Hierarchy (MuH), and Close the Circle (CtC).

These archetypes, described in Exhibit 2 (next page), lay the foundation for exploring opportunities to mitigate methane emissions from MSW, despite the waste management approaches deployed today.

Exhibit 2 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+)

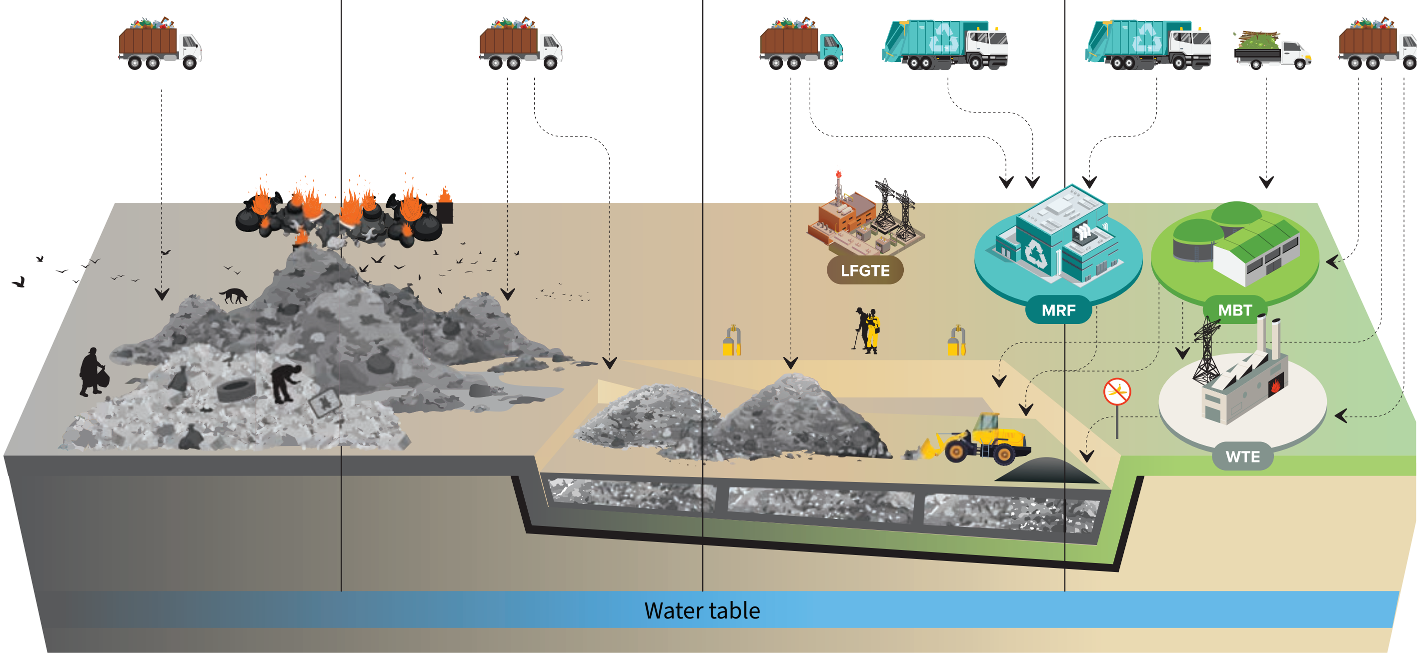
- Higher waste collection rate than BtB
- Limited or no source-separated organics or recycling
- Limited waste treatment
- Transitioning from dumpsites to sanitary landfills
- Illegal dumping and open burning of waste may occur

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 landfil
- 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

BtB archetype is characterized by low to medium collection rates, poor waste management systems, low recycling rates, and limited or no waste treatment prior to final disposal. Waste is disposed of at dumpsites without methane monitoring, capture, or other environmental control systems. Illegal dumping and open burning of waste are common. Although waste management regulations exist, enforcement is weak and existing standards do not address organic waste or the emissions from this waste. There is limited technical capacity because waste management infrastructure is lacking.

Because access to finance for capital projects is a major obstacle, these countries can start reducing methane emissions by building basic infrastructure or implementing relatively low-cost operational improvements at the dumpsites. This can include developing small-scale decentralized organics processing facilities, limiting waste pickers' access to dumpsites, installing landfill covers, and installing basic gas capture and control systems (GCCS). Example countries include the Dominican Republic, Guatemala, Nepal, Nigeria, Tajikistan, and Uganda.

BtB+ archetype shares certain characteristics with BtB in their waste management approach; however, BtB+ countries demonstrate relatively more advanced waste management practices. The main differences include higher collection rates and a noticeable progression from dumpsites to sanitary landfills. Although waste may be disposed of at dumpsites and illegal dumping and open burning may occur, countries in the BtB+ archetype have taken major steps toward 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. Example countries include Argentina, Brazil, Colombia, Ecuador, Mexico, the Republic of Serbia, and South Africa.

MuH archetype is characterized by universal or near universal collection rates and wide adoption of sanitary landfills with regulatory oversight and environmental control systems. Treatment of organic waste is minimal, but efforts are underway to reduce the generation of biodegradable waste at the source and expand organics recycling. Although standards are in place to capture and control methane emissions, these countries can move up the waste management hierarchy through more robust regulation and improved emissions transparency to phase out organic waste disposal and reduce fugitive methane emissions from landfills while advancing efforts to prevent food loss and waste. Example countries include Australia, Canada, New Zealand, and the United States.

CtC archetype is similarly characterized by universal or near universal collection and disposal in sanitary landfills. However, CtC countries are the least reliant on landfills for final disposal, with legislation in place that either bans landfilling of biodegradable materials or requires that biodegradable waste be stabilized before disposal. WTE technologies, which reduce the volume of waste disposed by incinerating waste, are commonly deployed. Although deploying these technologies largely avoids methane generation from the organic waste fraction, WTE facilities emit toxic air pollutants that have severe health impacts on nearby communities, and there is a missed opportunity to recover the carbon and plant nutrients. These countries can close the circle through food loss and waste prevention, organics diversion, and improved materials recovery. Example countries include Austria, Belgium, Finland, Germany, Japan, the Netherlands, Norway, Singapore, Sweden, and Switzerland.

Methane Mitigation Strategies for Municipal Solid Waste Management Archetypes

Opportunities exist across the waste management value chain to avoid or reduce methane emissions from MSW. This playbook outlines strategies to drive deep cuts in methane emissions across all four archetypes (BtB, BtB+, MuH, and CtC) post–waste generation.

Across the globe, managing solid waste relies primarily on disposal sites, with limited implementation of alternative management practices. Waste prevention or source reduction is the best option to manage waste, including biodegradable waste. Because food waste is the largest component of the organic waste stream, food loss and waste prevention is the best option to reduce methane emissions from MSW. Understanding the drivers of food loss and waste — including poor distribution and storage infrastructure, suboptimal packaging, poor food management, and consumer behaviors — is necessary to developing robust methane abatement solutions.

> **Waste prevention or source reduction is the best option to manage waste, including biodegradable waste. Because food waste is the largest component of the organic waste stream, food loss and waste prevention is the best option to reduce methane emissions from MSW.**

Discussing opportunities to reduce methane emissions before food waste is generated is beyond the scope of this report (see Exhibit 3). However, several studies have identified priority areas for reducing food loss and waste, including optimizing harvest, enhancing product distribution, optimizing product utilization, improving food rescue, and reshaping consumer behaviors.[12]

Exhibit 3 Methane mitigation strategies: Source reduction

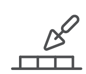
Building block	Building block element	Methane mitigation strategy	BtB	BtB+	MuH	CtC
Source reduction	Food loss and waste prevention	**Out of scope**				

RMI Graphic. Source: RMI analysis

Once waste has been generated, diverting biodegradable waste from disposal sites is the optimal strategy to reduce methane. Preventing biodegradable waste from reaching landfills and dumpsites avoids methane emissions from future waste streams. Waste diversion opportunities exist throughout waste generation, collection and transport, as well as recovery and treatment. These mitigation strategies and their applicable archetypes are summarized in Exhibit 4.

Placement of an icon in the following tables beside methane mitigation strategies denotes that the strategy is applicable to an archetype. For example, “Implement source separation of organics (SSO) programs” is applicable to all four archetypes, and “Leverage existing processing facilities” is only applicable to the MuH and CtC archetypes. Notably, a strategy that “does not apply” to an archetype indicates that the strategy is either incompatible with the current local waste management approaches or that countries within an archetype have already made significant advancement in this aspect, although further improvements can still be beneficial.

Exhibit 4 Methane mitigation strategies: Waste diversion

Building block	Building block element	Methane mitigation strategy	BtB	BtB+	MuH	CtC
Waste diversion	Generation	Implement source-separated organics (SSO) programs				
	Collection and transport	Expand collection infrastructure				
		Optimize collection frequency and routes				
	Recovery and Treatment	Leverage existing processing infrastructure				
		Develop centralized and decentralized processing facilities				
		Support end markets for organic waste–derived products				

RMI Graphic. Source: RMI analysis

For waste that has yet to reach the final disposal site, source reduction and organic waste diversion strategies should always be prioritized to avoid or reduce methane. However, for biodegradable waste that is not recovered or that has reached its final disposal site, capturing methane at dumpsites and landfills is the final opportunity to reduce methane emissions.

Strategies to optimize the design and operation at landfills and dumpsites to enhance gas capture and minimize fugitive emissions are presented in Exhibit 5 (next page). These strategies are not exhaustive due to the unique differences across disposal sites. A comprehensive list of design and operational considerations can be found in *Key Strategies for Mitigating Methane Emissions from Municipal Solid Waste*.[13]

Exhibit 5 **Methane mitigation strategies: Waste disposal**

Building block	Building block element	Methane mitigation strategy	BtB	BtB+	MuH	CtC
Waste disposal	End-of-life disposal	Minimize surface area of the active working face	✓	✓	✓	✓
		Install daily cover	✓	✓		
		Install intermediate and final covers	✓	✓	✓	
		Use biocovers or biofilters to oxidize methane	✓	✓	✓	✓
		Install GCCS and optimize gas collection and flare efficiency	✓	✓	✓	✓

RMI Graphic. Source: RMI analysis

The strategies discussed above do not include opportunities to reduce methane emissions that often span the entire waste management value chain. These cross-cutting opportunities include developing robust policy and regulatory frameworks, enhancing emissions transparency, improving access to finance, and furthering stakeholder awareness and capacity building. Exhibit 6 (next page) summarizes policy instruments that can be used to expand existing regulatory frameworks to improve organic waste diversion, emissions detection and quantification, and methane capture and control.

Exhibit 6 **Methane mitigation strategies: Cross-cutting component, policy and regulatory framework**

Building block	Building block element	Methane mitigation strategy	BtB	BtB+	MuH	CtC
Cross-cutting component	Policy and regulatory framework	Set minimum thresholds for mandatory source segregation for large waste generators	✓	✓	✓	✓
		Phase out organic waste disposal	✓	✓	✓	✓
		Ban incineration of recyclable materials including organic waste			✓	✓
		Integrate the informal recycling sector	✓	✓		
		Implement landfill taxes and pay-as-you-throw models	✓	✓	✓	
		Develop procurement standards and set targets for organics-derived products	✓	✓	✓	✓
		Develop landfill design, operational, and monitoring standards to capture and control methane	✓	✓		
		Require GCCS at disposal sites	✓	✓	✓	✓
		Require more frequent emissions monitoring		✓	✓	✓
		Adopt policies that encourage the use of advanced monitoring technologies			✓	✓
		Mandate greenhouse gas reporting	✓	✓		
		Implement compliance mechanisms	✓	✓		
		Streamline permitting and zoning process for critical infrastructure projects	✓	✓	✓	✓

Policies on waste diversion   Policies on waste disposal   Policies on emissions transparency   Other policies

RMI Graphic. Source: RMI analysis

Exhibit 7 summarizes opportunities to improve emissions transparency through improved data collection and availability. More comprehensive and up-to-date data, including waste characterization, waste flow, and emissions data lay the foundation for identifying methane abatement opportunities. More stringent and standardized emissions reporting can also help guide resource deployment for targeted reduction in methane emissions.

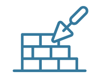
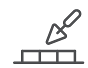
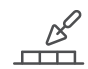
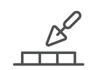
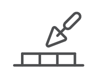
Exhibit 7 Methane mitigation strategies: Cross-cutting component, emissions transparency

Building block	Building block element	Methane mitigation strategy	BtB	BtB+	MuH	CtC
Cross-cutting component	Emissions transparency	Conduct and/or update waste characterization studies				
		Collect robust waste sector data				
		Leverage advanced monitoring technologies to improve emissions quantification				
		Make waste and emissions data and methodology publicly available				

RMI Graphic. Source: RMI analysis

High up-front cost combined with limited access to affordable finance can often pose significant challenges to municipalities or waste management facility owners in deploying critical infrastructure such as collection vehicle fleets, treatment technologies, GCCS, or sanitary landfills. Exhibit 8 (next page) summarizes strategies to de-risk projects, improve bankability of projects, and unlock finance, thus reducing the entry barrier to implementing these solutions.

Exhibit 8 Methane mitigation strategies: Cross-cutting component, finance

Building block	Building block element	Methane mitigation strategy	BtB	BtB+	MuH	CtC
Cross-cutting component	Finance	Provide subsidies for proven technologies				
		Provide affordable finance				
		Reduce the cost of finance through risk sharing mechanisms such as blended finance				
		Develop or access project preparation facilities				
		Guarantee revenue through procurement contracts and offtake agreements				
		Improve profitability by diversifying revenue streams				
		Improve cost recovery through pay-as-you-throw models and other innovative pricing and tariff structures				

RMI Graphic. Source: RMI analysis

While policy, finance, and emissions transparency are critical to advancing emissions reduction efforts, stakeholder awareness and capacity building should not be ignored (see Exhibit 9, next page). Developing technical capacity among regulators and key facility personnel is necessary to optimize methane abatement. At the same time, educating other key stakeholder groups through awareness and outreach programs can help improve their reception of new initiatives, encourage participation, and promote success.

Exhibit 9 **Methane mitigation strategies: Cross-cutting component, stakeholder awareness and capacity building**

Building block	Building block element	Methane mitigation strategy	BtB	BtB+	MuH	CtC
Cross-cutting component	Stakeholder awareness and capacity building	Build technical capacity among waste service providers				
		Build technical capacity among regulators and policymakers				
		Implement educational awareness and outreach programs				

RMI Graphic. Source: RMI analysis

Conclusion and Recommendations

Reducing methane emissions is a critical step toward limiting near-term warming, and the waste sector remains a significant untapped opportunity. This playbook describes four waste management archetypes based on current solid waste management practices in different parts of the world. The authors explore opportunities within each archetype to improve waste management and reduce methane emissions from MSW (see Exhibit 10, next page).

For the BtB archetype — where many countries still lack some basic infrastructure — the authors recommend that countries consider robust infrastructure build-out in the long term to improve operations. Recognizing existing financial constraints, the authors suggest building relatively low-cost basic infrastructure such as small-scale composting and anaerobic digestion, and installing landfill covers and landfill gas (LFG) capture systems in the near term. Capacity building for waste service providers is crucial to improving long-term sustainability of projects. Access to low-cost financing is also critical to project implementation in these countries. By implementing some of these solutions, BtB countries can improve their current waste management practices, enabling them to move toward the BtB+ archetype.

For the BtB+ archetype with a higher waste collection rate and better infrastructure for waste collection and disposal, the authors recommend continuing the rehabilitation of dumpsites to sanitary landfills. These systems should be fitted with GCCS to reduce fugitive emissions. As these countries transition to the use of sanitary landfills for waste disposal, it is also important to routinely review and update existing MSW policies and regulations to reflect sustainable practices for managing organic waste and emissions from decomposed waste. Similar to BtB countries, capacity building for facility operators and other waste service providers is also critical to improving long-term viability of methane abatement projects in BtB+ countries.

By progressively transitioning from dumpsites to sanitary landfills coupled with more robust regulations, improving technical capacity for waste service personnel, and accessing affordable finance, BtB+ countries will be able to move toward the MuH archetype.

Exhibit 10 Key levers for progressing across municipal solid waste management archetypes

RMI Graphic. Source: RMI analysis

For the MuH archetype where sanitary landfills are utilized and LFG capture and control systems are more widely adopted, the authors recommend strengthening SSO programs and phasing out disposal of organic waste from landfills. Although regulatory provisions to detect and repair leaks through periodic surface emissions monitoring often exist, there are opportunities to improve the robustness of these frameworks. Developing more robust policies to phase out landfilling of organic waste and to more efficiently capture methane from existing waste is necessary to optimize methane emissions reduction. As MuH countries reduce the landfilling of organic waste and improve gas capture efficiency at existing landfills, these countries can progress toward an aspirational system that is more closely aligned with the waste management hierarchy.

For the CtC archetype where countries have widely adopted WTE technologies and have laws and regulations that require the treatment and/or stabilization of waste before landfilling, the authors recommend instituting policies that ban incineration of organic waste and diverting this waste for beneficial end uses. This will allow these countries to similarly progress toward a system that more closely aligns with the waste management hierarchy and promotes a circular economy.

Endnotes

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