

Executive Summary

What a Waste 3.0

Global Snapshot of Solid Waste Management toward Circularity until 2050

Ed Cook, Kremena Ionkova, Perinaz Bhada-Tata,
Sonakshi Yadav, and Frank van Woerden

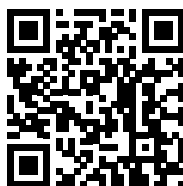


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toward Circularity until 2050**

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**Ed Cook, Kremena Ionkova, Perinaz Bhada-Tata,
Sonakshi Yadav, and Frank van Woerden**

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Purpose and Audience

What a Waste 3.0 is the third edition of the World Bank Group's *What a Waste* series, following the 2012 and 2018 publications. It updates and expands these earlier publications and provides a global reference dataset on municipal solid waste in the context of a transition toward circularity, drawing on the most recent publicly accessible data from 217 countries and economies and 262 cities. This edition consolidates data on waste generation, composition, collection, treatment, and disposal, and presents trends by region and income group. It also includes information on legislation, institutional arrangements, plastics management, private sector participation, employment, environmental impacts, and the costs and financing of municipal waste services.

The publication is intended as a technical reference, offering structured data to inform planning, benchmarking, and analyses. It does not provide policy recommendations or endorse specific approaches. Instead, by making prevailing data and trends widely accessible, it supports evidence-based decision making and informed dialogue across the waste sector. Against the backdrop of a mounting global waste crisis—with rising volumes, environmental degradation, and widening service gaps—*What a Waste 3.0* underscores the scale and urgency of the challenge. By presenting the most comprehensive and contemporary publicly accessible dataset on municipal waste, it offers a common foundation for coordinated action.

What a Waste 3.0 is designed for national and local governments, development institutions, researchers, private sector, and practitioners working in solid waste management, the circular economy, and broader urban development. The publication is intended to be used alongside the accompanying online datasets, which provide open access to detailed country- and city-level data for further analysis and application.

With decades of engagement in the sector, and as the largest provider of development financing for solid waste management globally, the World Bank Group is pleased to offer *What a Waste 3.0*. The report was developed with input from partners, technical experts, and data contributors worldwide—as a contribution to the global knowledge base and to support countries and economies in building more effective and sustainable waste systems that enable greater resource recovery and advance the transition toward circularity.

Contents in main report

Foreword

Acknowledgments

Abbreviations and Acronyms

Summary of Findings

1. Introduction

- 1.1 Definition of Regions and Income Groups
- 1.2 A Note on Data

2. At a Glance: A Global Picture of Solid Waste Management toward Circularity

- 2.1 Waste Generation
- 2.2 Waste Composition
- 2.3 Waste Collection
- 2.4 Progress toward Achieving Sustainable Development Target 11.6.1
- 2.5 Waste Treatment and Disposal
- 2.6 Self-management of Uncollected Waste
- 2.7 Plastic Waste
- 2.8 Special Wastes
- 2.9 Waste Imports

3. Regional Snapshots

- 3.1 East Asia and Pacific
- 3.2 Europe and Central Asia
- 3.3 Latin America and the Caribbean
- 3.4 Middle East and North Africa
- 3.5 North America
- 3.6 South Asia
- 3.7 Sub-Saharan Africa

4. Scenarios for Municipal Solid Waste Management and Circularity until 2050

- 4.1 Overview of Scenarios
- 4.2 Scenarios for Waste Generation
- 4.3 Scenarios for Municipal Solid Waste Collection Coverage
- 4.4 Scenarios for Municipal Solid Waste Recycling and Composting
- 4.5 Scenarios for Municipal Solid Waste Treatment, Disposal, and Uncollected Waste

5. Waste and Climate

- 5.1 Greenhouse Gas Emissions from Solid Waste Management
- 5.2 Projected Greenhouse Gas Emissions
- 5.3 Solid Waste in Nationally Determined Contributions

6. Waste Administration, Operations, and Jobs

- 6.1 Solid Waste Management Laws and Regulations
- 6.2 Planning for Solid Waste Management
- 6.3 Waste Management Operations
- 6.4 Jobs

7. Costs and Financing of Solid Waste Management

- 7.1 Waste Management Costs
- 7.2 Current and Future Cost Estimates
- 7.3 Waste Management Financing

Appendix A Waste Generation and Projections by Country or Economy

Appendix B Waste Treatment and Disposal by Country or Economy

Appendix C Summary Methodology

Foreword

Solid waste is one of the most visible by-products of human prosperity—and one of the most underestimated threats to our shared future.

Trash discarded on a city street or a neighborhood dump does not remain local. Plastic carried by rivers reaches the ocean; methane from decomposing food escapes into the atmosphere; and open burning pollutes the air we all breathe. Waste is a municipally managed issue with consequences that are both local and global.

In 2022, the world generated 2.6 billion tonnes of municipal solid waste. This new edition of our *What a Waste* report reveals that total volumes could soar to 3.9 billion tonnes by 2050—a 50 percent increase—with the fastest growth projected in Sub-Saharan Africa (124 percent) and South Asia (99 percent). Today, about 30 percent of global waste is still either openly dumped or left uncollected, compounding risks to local economies, public health, and the environment.

Meeting this challenge will demand significant, sustained investment. Achieving universal and sustainable waste collection and management will require steady public spending in the range of 0.3–0.8 percent of GDP. Yet the costs of inaction—from worsened flooding and pollution, to declining property values and tourism losses, to foregone jobs and missed economic opportunities—are far higher.

But a different future is within reach. With strategic action, countries can cap total waste generation even as economies grow; expand collection coverage and improve service quality; reduce system costs relative to business as usual; and unlock millions of good jobs across the value chain. Waste services, resource recovery, and circular economy industries already employ millions of workers. With the right policies, investments, and support for small- and medium-sized enterprises and the informal workforce, they can create many more jobs.

The World Bank Group stands ready to help countries and cities turn this waste challenge into an opportunity for resilient, inclusive growth. As the world's largest official development financier of solid waste management, the World Bank pairs deep sector knowledge with concessional finance and private capital solutions to support reform and investment—from waste reduction and collection to treatment and recovery.

What a Waste 3.0 offers the most comprehensive and publicly accessible global dataset on municipal solid waste, covering 217 countries and economies and 262 cities. Building on the 2012 and 2018 editions, it consolidates data on waste generation, composition, collection, treatment, and disposal; tracks trends by region and income; and maps legislation, institutions, private participation, employment, environmental impacts, and costs and financing.

Although solid waste is generated locally, its impacts—and opportunities—are global. By aligning data with ambition and finance with reform, we can turn the mounting

waste crisis into an opportunity to build cleaner, more resilient, and livable cities—creating jobs today while safeguarding resources for tomorrow.



Ming Zhang
World Bank Group Director
Global Department for Urban, Subnational Finance,
Tourism and Disaster Management
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Nikola Doychinov, Heather Nichole Hogan, Costas Velis, Tanzir Chowdhury, Caroline Bradley, Silpa Kaza, Rieko Kubota, Ali Abedini, Nuru Lama, Gianluca Forlani, and Konstantinos Verganelakis authored specific sections of the study as detailed below.

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Summary of Findings

The world is at a critical juncture in managing its growing waste. Rapid population growth, accelerating urbanization, rising incomes, and increased consumption are driving a surge in municipal solid waste¹ generation that is outpacing the capacity of local systems and municipal budgets. As a result, cities and communities worldwide are struggling to keep up with mounting quantities of waste. When waste is not managed well, the consequences are far reaching: environmental pollution intensifies, greenhouse gas (GHG) emissions rise, and valuable natural resources are wasted. These threaten public health and the environment and undermine economic development and the livability of cities. Yet, within the crises lies an opportunity. By investing in more efficient, inclusive, and sustainable waste management systems, countries can unlock new avenues for economic growth, job creation, and innovation. Improved waste management systems that embrace circular economy principles, where materials are reused and value is retained, can transform waste from a burden into a driver of sustainable development, benefiting both local communities and the global environment. To fully grasp the scale and urgency of today's challenges, as well as the opportunities they present, this *What a Waste* report offers the most up-to-date data and statistical analytics on global solid waste management performance levels and trends.

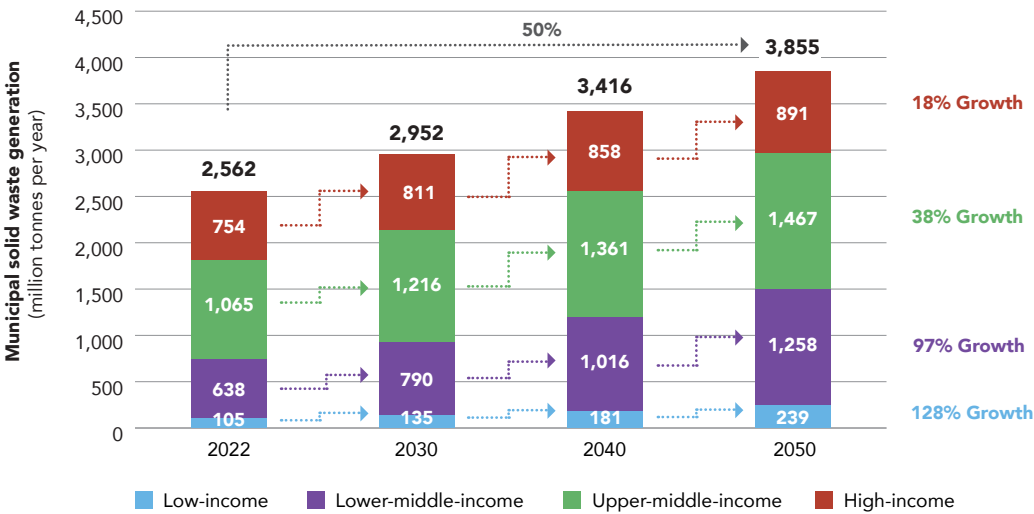
Global Picture of Solid Waste Management toward Circularity

What a Waste 3.0 estimates that global waste generation is rising faster than previously projected. While the 2018 *What a Waste 2.0* report estimated that the world would generate 2.59 billion tonnes of waste by 2030 (Kaza et al. 2018), the most current figures show that 2.56 billion tonnes were already produced by 2022.²

The distribution of waste generation is uneven across country income groups and regions. High-income countries, while comprising 16 percent of the global population, generated 29 percent of the world’s waste in 2022 and had the highest per capita waste generation. Upper-middle-income countries, accounting for 36 percent of the population, produced the largest share of global waste at 42 percent. Lower-middle-income countries represented about 40 percent of the population and generated 25 percent of global waste, whereas low-income countries, with 9 percent of the population, produced 4 percent of the waste. Regionally, East Asia and the Pacific generated the largest share of global waste at 33 percent, whereas the Middle East and North Africa produced the least at 6 percent.

Under a business-as-usual scenario, global waste generation is expected to grow from 2.56 billion tonnes in 2022 to 3.86 billion tonnes by 2050, a 50-percent increase. The increase in low-income countries is expected to more than double by 2050, with the fastest growth projected in Sub-Saharan Africa and in South Asia (figure S.1).

Figure S.1 Projected waste generation by income group



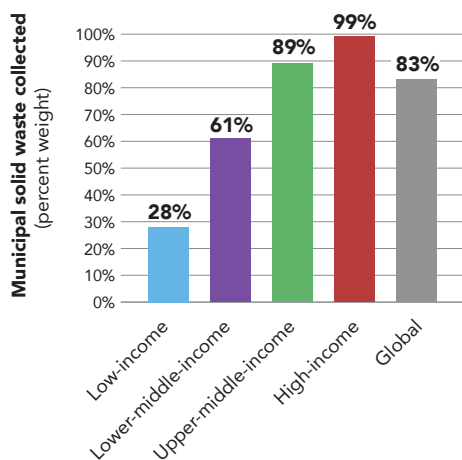
Source: Original figure for this report.
Note: Growth rates in colored text show proportional increase in waste generation between 2022 and 2050.

Food and garden waste account for the majority of municipal waste composition in low-income countries, making up 52 percent of the total waste generated. By contrast, higher-income countries see their waste streams dominated by dry recyclable materials, textiles, and waste electrical and electronic equipment (WEEE), which together comprise about 50 percent of their municipal waste. Plastics constitute approximately 12.5 percent of municipal solid waste globally, with the proportion ranging from 8.1 percent in low-income countries to 13.1 percent in upper-middle-income countries. Single-use plastics are estimated at 65 percent of all municipal solid waste plastics generated worldwide each year.

Waste collection rates show stark disparities across income levels and regions (figure S.2). High- and upper-middle-income countries achieve high collection rates, with high-income regions such as North America reporting rates close to 100 percent and upper-middle-income countries reaching about 89 percent. By contrast, lower-middle-income countries collect 61 percent and low-income countries collect only 28 percent of their waste. These gaps are also evident regionally, with South Asia and Sub-Saharan Africa having the lowest collection rates worldwide at 67 and 31 percent, respectively.

Global waste management practices differ markedly by income level and region. Although nearly 100 percent of municipal solid waste in high-income countries is managed in controlled facilities³—meeting the Sustainable Development Goal (SDG) target for safe waste management (UN-Habitat and UNSD 2018)—only 3 percent of waste in low-income countries is managed in controlled facilities, with most waste either uncollected or disposed of in dumpsites. Globally, landfills remain the most common method of waste management, accounting for 29 percent of all waste, followed by materials recovery through recycling, composting, and anaerobic digestion⁴ at 21 percent, and incineration with energy recovery at 20 percent. The remaining 30 percent of waste generated worldwide is either openly dumped or not collected at all (figure S.3), a challenge most acute in low-income countries and rapidly growing regions such as Sub-Saharan Africa and South Asia (figure S.4).

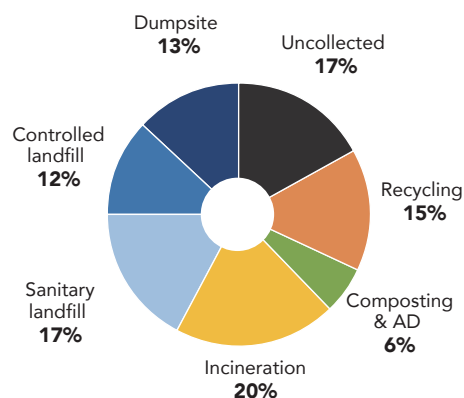
Figure S.2 Municipal solid waste collection rates by income group



Source: Original figure for this report.

Note: Mean collection coverage (percent, weighted by the total mass of waste collected in each income group in 2022).

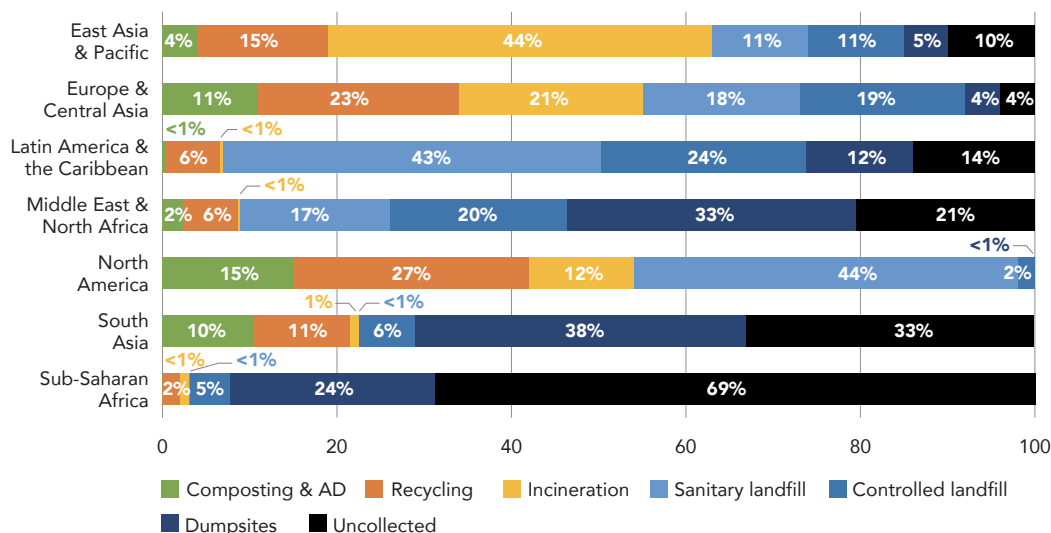
Figure S.3 Global municipal solid waste treatment and disposal



Source: Original figure for this report.

Note: Mean treatment and disposal (percent, weighted by the total mass of waste generated in 2022).

AD = anaerobic digestion.

Figure S.4 Municipal solid waste treatment, disposal, and uncollected waste by region

Source: Original figure for this report.

Note: Proportion of uncollected and treated waste multiplied by the weight of waste generated in 2022. AD = anaerobic digestion.

Food waste presents a unique challenge due to its widespread prevalence, culturally determined practices, and the complexities involved in collecting uncontaminated organic waste. It constitutes the largest share of municipal solid waste globally, accounting for 38 percent. Although composting and anaerobic digestion are the most sustainable treatment options, their adoption remains limited. Globally, only 6 percent of waste is composted or processed through anaerobic digestion. In low-income countries, this figure drops to less than 1 percent.

Plastic waste is of significant concern. Nearly 29 percent of all plastic waste—or 93 million tonnes per year—is mismanaged; 13 percent is poorly managed in uncontrolled facilities such as dumpsites, and 16 percent remains uncollected. Middle-income countries are the leading source of unmanaged plastic waste, generating 87 percent of the global total. Sub-Saharan Africa, South Asia, and East Asia and the Pacific produce the largest quantities of unmanaged plastic waste—15 million tonnes, 14 million tonnes, and 12 million tonnes, respectively.

Nearly all countries have legislation governing solid waste management and 70 percent of countries report having national solid waste management strategies. Local governments often introduce additional regulations, such as requirements for source segregation, to strengthen national laws.

Globally, 88 percent of countries have national policies targeting plastics, with upstream measures like taxes, bans, and fees on imports and production being the most widespread. Extended producer responsibility⁵ is commonly adopted to engage producers and suppliers of plastic materials in the management and recycling of plastic products (OECD 2016). However, its practical implementation to

date has largely been limited to high-income countries. Challenges such as limited regulatory capacity, data availability and reliability, and insufficient enforcement mechanisms hinder the widespread impact of such instruments. Measures such as deposit return schemes for beverage containers are less common.

Solid waste management is predominantly a local responsibility, with municipal or metropolitan authorities overseeing most waste services. Direct central government involvement in waste operations is uncommon and generally limited to smaller countries and island states. About half of waste management operations are publicly run, whereas the rest is split between private and mixed public-private arrangements. Private sector participation is most prevalent in treatment and disposal, often through concession contracts, with service and franchise contracts also playing a role. Despite the potential benefits, cooperation between municipalities for shared service provision remains limited, which can hinder the achievement of greater efficiency and cost savings.

Waste management and recycling activities are important sources of employment, estimated to engage about 18 million urban waste workers, equivalent to about 0.3 percent of the global urban population. In lower-income countries, most of these jobs are concentrated in waste collection, sorting, and recycling, with the informal sector playing a particularly critical role. In lower-income countries, informal waste workers are essential to the functioning of solid waste management systems, yet they often operate under precarious conditions, facing social stigma, limited legal protections, and significant health risks. By contrast, in high-income countries, a growing share of employment is generated indirectly through industries that supply goods and services to, or benefit from, the waste sector. Indirect employment is not captured in the employment estimates within this report. Systematic public reporting on employment remains largely confined to high-income and some middle-income countries, contributing to concerns about data reliability and the visibility of informal sector contributions.

Costs and Financing

The global cost of municipal waste management already exceeds US\$250 billion annually and is projected to rise to US\$426 billion by 2050 if existing practices continue. These costs vary significantly across countries, shaped by factors such as collection and treatment methods, community participation, labor and fuel expenses, and the degree of automation. While basic waste management systems in lower-income countries cost at least US\$40-US\$45 per tonne, depending on local conditions, advanced systems that incorporate recycling and landfill diversion often exceed US\$120 per tonne. This places substantial financial pressure on local authorities, with implications for the sustainability and effectiveness of service delivery.

Municipal waste management is an expensive service that local governments provide, placing significant fiscal pressure on public budgets especially in low- and

middle-income countries. This *What a Waste* reports that solid waste management absorbs, on average, 6 percent of municipal budgets, with cities in lower-income countries spending a higher than average share. Despite this expenditure, many cities struggle to achieve full service coverage, maintain basic infrastructure, or recover operational costs. Full cost recovery through user fees is predominantly achieved in high-income countries, whereas most low- and middle-income countries supplement financing with support from local, regional, and central government budgets. User fees for waste management services vary widely, ranging from as little as US\$10 per household per year in low-income countries to over US\$500 in high-income countries, with average fees of US\$30 and US\$260, respectively. Actual costs frequently exceed available financing from user fees, budget allocations, and other sources combined, resulting in underinvestment and persistent service gaps that reinforce one another.

This report estimates that, in middle-income countries, establishing basic but universal systems of collection and environmentally sound management of municipal waste, would require approximately 0.3 percent of gross domestic product (GDP), with more advanced systems approaching 0.5 percent. In low-income countries, achieving basic universal coverage may require close to 0.8 percent of GDP, reflecting lower baseline service levels and smaller economies. High-income countries would need at least one-third of a percent of their GDP.⁶ By comparison, reported public expenditure on solid waste management is less than 0.15 percent of GDP in about three-quarters of low- and middle-income countries and about 0.3 percent in high-income countries. While reported public spending in low- and middle-income countries falls well below estimated financing needs, actual outlays are likely higher, as budget data often exclude expenditures by private providers and state-owned enterprises.

In a business-as-usual scenario, low- and lower-middle-income countries face substantial investment needs, estimated at US\$556 billion between 2022 and 2050. Mobilizing investments at this scale is likely to require a mix of domestic fiscal resources, development assistance, and private capital; between 2003 and 2021, official development finance commitments to the sector totaled only US\$14.5 billion, including US\$1.0 billion for low-income countries and US\$5.9 billion for lower-middle-income countries (Lerpiniere, Wilson, and Velis 2025). While the public sector remains central to planning, regulation, and core service provision, additional financing from private sources is likely to play an increasingly important role, particularly for advanced treatment and recovery facilities. Private sector participation in waste management depends on predictable revenue streams, underpinned by tariff policies, fee collection systems, and policy and regulatory frameworks that create conditions attractive to private operators. Reliable sector financing therefore remains essential to provide the foundation for private participation and to ensure continuous, high-quality service delivery.

The waste sector has benefited from innovative financial mechanisms. It has established a strong presence in carbon markets, particularly through its engagement with the earlier Clean Development Mechanism,⁷ and is now poised to benefit from new

opportunities under Article 6 of the Paris Agreement. Participation in these markets allows waste operators to attract investment for waste treatment technologies, such as landfill gas capture and utilization, composting, and waste-to-energy, which help reduce GHG emissions. Good governance, transparent monitoring and reporting systems, and alignment with national climate objectives to ensure environmental integrity and maximize the impact of carbon finance are required to access climate financing and realize sought objectives (World Bank Group 2024; 2025).⁸

As waste quantities continue to grow—especially in low- and lower-middle-income countries where existing service coverage and infrastructure remain below adequate levels—the challenge is to address existing shortfalls and meet future demand. Without accelerating investments, existing service gaps will widen, leaving countries further behind and locking in higher environmental, health, and economic costs. The urgency is therefore twofold: to expand systems fast enough to keep pace with rising waste volumes, and to raise performance well above prevailing baselines to avoid compounding the broader economic costs of inaction and damages from unmanaged waste.

Impacts and Opportunities

Solid waste management lies at the nexus of local service delivery, livability, and economic development, and is increasingly central to global environmental sustainability. At the local level, it is essential to public health, environmental quality, climate resilience, and the functioning of cities. Effective, reliable, and inclusive waste services reduce the spread of disease, prevent contamination of water, soil, and air, mitigate flooding caused by blocked drainage, and support a safe, dignified urban environment. Clean cities contribute to local economic development by enhancing competitiveness and strengthening the overall business environment. As cities transition toward more circular economies, where waste-derived materials are reintegrated into productive use, solid waste management is firmly established as a driver of investment, private sector participation, and job creation.

Globally, how waste is managed has significant implications for climate change, pollution, and the sustainable use of finite natural resources. Open burning and unmanaged organic waste release GHGs including methane and black carbon, which contribute to climate change and deteriorating air quality. The Global Methane Assessment identified the waste sector as the third-largest global source of methane, responsible for approximately 20 percent of global anthropogenic methane emissions and prioritized the sector for mitigation action (UNEP and CCAC 2021). Inadequate waste systems are also the primary source of plastic waste leakage into rivers and oceans, which severely damages marine ecosystems and threatens livelihoods and biodiversity (World Bank 2022a; 2022b). Poor waste practices result in the permanent loss of valuable materials, including metals, minerals, and nutrients, undermining efforts to conserve finite natural resources and transition to more resource-efficient economies.

These wide-ranging impacts underscore the need to view waste management as both an urgent public good challenge and a strategic opportunity to unlock significant local economic, social, and ecological benefits.

Economically, the case for effective waste management is compelling, as the costs of inaction considerably exceed costs required for sound waste systems. The economic costs of uncollected waste that is burned, dumped, or discharged into waterways, and of damage from flooding caused by blocked drains and reduced stormwater capacity, have been shown to surpass the financial costs of properly operating waste management systems. Broader societal and opportunity costs—such as the erosion of trust in local authorities and impacts on community dignity and pride—are rarely quantified but remain critical for local development and societal well-being. Investing in sound waste management avoids these costs and delivers broader benefits: cleaner, livable cities that attract talent and investment, higher property values, jobs, and growth in related industries, such as recycling and manufacturing.

Social benefits include greater inclusivity and expanded employment opportunities, with jobs generated in waste services and resource recovery across formal and informal sectors. Integrating informal workers is critical for advancing social equity and strengthening communities. Additional employment is also created upstream through research, redesign, and remanufacturing for recyclability. As cities embrace circular economies, waste management drives secondary job creation and broader economic benefits.

Environmental benefits relate chiefly to pollution reduction and climate change mitigation. Opportunities are substantial and span both upstream and downstream interventions for plastic pollution. Upstream, redesigning products, reducing unnecessary packaging, and adopting alternative materials can prevent plastic waste at its source. Downstream, achieving universal waste collection, and eliminating open dumping are essential to prevent plastics from leaking into the environment. Strengthening integrated waste management systems and investing in circular economy approaches are also critical to protect ecosystems and reduce pollution.

The waste sector offers significant opportunities in climate mitigation. In 2022, GHG emissions from solid waste management activities were estimated at approximately 1.28 billion tonnes of carbon dioxide equivalent per year, with methane accounting for the vast majority at 1.15 billion tonnes of carbon dioxide equivalent annually. If existing practices continue, GHG emissions from solid waste management are projected to rise sharply, reaching 1.84 billion tonnes of carbon dioxide equivalent by 2050, a 43-percent increase from 2022 levels.

Food loss and food waste⁹ are major contributors to these emissions, with possibly one-third of all food produced globally lost or discarded each year (FAO 2011). Addressing food loss and food waste is essential for reducing emissions but also improving food security, protecting natural resources and achieving climate goals. It remains among the most complex issues facing the world today.

Reflecting the urgency and potential for impact, it is notable that 156 countries have recognized the climate mitigation potential of improved waste and plastic manage-

ment by including the waste sector in their Nationally Determined Contributions (NDCs).¹⁰ Prioritized measures include composting and methane capture as well as recycling. However, financing and regulatory challenges constrain implementation, with most commitments reported as dependent on international support.

Scenarios for Municipal Solid Waste Management toward Circularity to 2050

What a Waste 3.0 has developed alternative scenarios for municipal solid waste management through 2050, providing a framework for understanding how different policy choices and levels of ambition could shape the future of global waste.

This report presents three scenarios: business as usual, low ambition, and high ambition. The business-as-usual scenario extends prevailing trends, projecting a significant increase in global waste generation—from 2.56 billion tonnes in 2022 to 3.86 billion tonnes in 2050. By contrast, the high-ambition scenario models a future where waste generation is capped at prevailing levels, despite ongoing population and economic growth, through a combination of targeted interventions and improved waste management practices. The low-ambition scenario represents a middle path, achieving half the reduction of the high-ambition scenario, with global waste reaching 3.12 billion tonnes in 2050. Importantly, these scenarios are designed to support long-term planning and policy development, by considering waste reduction and improvements in waste collection and management.

Across all scenarios, waste collection coverage expands significantly, with the most notable gains in low-income countries. Waste treatment and disposal practices also see substantial progress while the share of uncollected and openly dumped waste declines sharply. These achievements vary by income group, with high- and upper-middle-income countries increasing recycling and composting, whereas low- and lower-middle-income countries eliminate open dumping and expand access to recycling, composting, and sanitary landfilling. Collectively, the scenarios highlight the scale of the challenge and the significant potential for progress in waste management toward circularity.

The financial costs and GHG emissions were estimated for the three scenarios. The low-ambition and high-ambition scenarios result in lower overall costs compared to the business-as-usual scenario, primarily owing to reduced waste volumes.¹¹ Conversely, in low- and lower-middle-income countries, investment and annual costs rise under all scenarios, driven mainly by low baseline conditions with widespread uncollected waste and open dumping. The scenarios demonstrate the substantial climate benefits in GHG emissions that can be achieved through improved waste management. Both the low- and high-ambition scenarios project a decline in global GHG emissions from the waste sector between 2030 and 2050, with estimates of 1.33 billion tonnes of carbon dioxide equivalent and 0.91 billion tonnes of carbon dioxide equivalent, respectively, by 2050.

The scenarios are intended to inform and guide discussion and policy action on alternative future pathways for the waste sector. Redirecting a modest share of GDP into well managed, essential systems can lock in basic service reliability, avert escalating economic losses and pollution, support job creation, and improve urban livability. The scenarios highlight how greater ambition, where waste prevention and minimization are paired with upstream measures toward substantially higher reuse, recycling and recovery rates, can deliver further climate, environmental, and resource efficiency benefits, generate additional opportunities for job creation and economic development, and contribute to the achievement of global sustainability goals.

Notes

1. Municipal solid waste is defined to include waste from households and residential establishments, including bulky waste, similar to household waste from commerce and trade, office buildings, institutions, and small businesses; yard and garden waste; street sweepings; the contents of litter containers; and market waste, if managed as household waste. The definition excludes waste from municipal sewerage networks and treatment, as well as waste from construction and demolition activities.
2. This surpassing of earlier projections is partly due to improved data quality and updated methodologies that now include previously unmeasured waste streams, such as uncollected waste.
3. The term “controlled” is defined by the Waste Wise Cities Tool through a set of ladders of control applied for land disposal, incineration, and other recovery facilities. In this edition of *What a Waste*, “controlled” refers specifically to all collected waste that is treated in facilities other than dumpsites. The Waste Wise Cities Tool is available at: <https://unhabitat.org/wwc-tool>.
4. It should be noted that while presented together with composting, anaerobic digestion does not necessarily result in material recovery.
5. The Organisation for Economic Co-operation and Development (OECD) defines extended producer responsibility as follows: “Extended producer responsibility is a policy approach that makes producers responsible for their products along the entire lifecycle, including at the post-consumer stage. By doing so, it helps achieve environmental goals such as recycling targets. At the same time, EPR generates funding from producers that help to pay for the collection, sorting and recycling of waste products, as well as generates detailed information on production, products, waste generation and treatment.” OECD 2016.
6. All estimates were conducted at the country income-group level using combined 2022 GDP.
7. The Clean Development Mechanism (CDM) is a UN program under the Kyoto Protocol that allows emission reduction projects in developing countries to earn tradable carbon credits. For more information, see <https://cdm.unfccc.int/>.
8. For a discussion on waste sector projects accessing carbon finance through the Clean Development Mechanism and opportunities under Article 6 of the Paris Agreement, see <https://hdl.handle.net/10986/43183>. For an overview of the growth of carbon markets, the operationalization of Article 6, and implications for sectors including waste, see <https://hdl.handle.net/10986/42016>.
9. Food loss occurs along the supply chain, especially in regions lacking infrastructure, cold storage, and efficient logistics, while food waste happens at retail and consumer levels due to spoilage, over-purchasing, aesthetic standards, or expiry dates. FAO 2013.
10. Nationally Determined Contributions (NDCs) are country-owned climate action plans required under Article 4.2 of the Paris Agreement. They set out each country’s commitments to reduce GHG emissions and adapt to climate change and are updated every five years to reflect increased ambition and progress. NDCs serve as stepping stones toward the global goal of limiting temperature rise and achieving climate resilience.
11. The estimates focus only on direct waste management costs and do not account for additional expenses associated with upstream prevention and minimization measures. Such measures will require further investments from producers and distributors involved in diverting materials and products.

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