Best Practices for Solid Waste Management:

A Guide for Decision-Makers in Developing Countries

October 2020
EPA 530-R-20-002

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United States Environmental Protection Agency
Office of Resource Conservation and Recovery

October
2020

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Acronyms and Abbreviations

AD	Anaerobic Digestion
CBI	Climate Bonds Initiative
CCAC	Climate and Clean Air Coalition
CEC	Commission for Environmental Cooperation
EPR	Extended Producer Responsibility
e-waste	Electronic Waste
GMI	Global Methane Initiative
Guide	*Best Practices for Solid Waste Management: A Guide for Decision-Makers in Developing Countries*
ISWA	International Solid Waste Association
JSC-H&B	Joint Services Council for Hebron and Bethlehem
LFG	Landfill Gas
MRF	Material Recovery Facility
NGO	Nongovernmental Organization
PET	Polyethylene Terephthalate
PETCO	PET Recycling Company NPC
PPP	Public-Private Partnership
QR	Quick Response
S.M.A.R.T.	Specific, Measurable, Attainable, Relevant, and Timely
UNEP	United Nations Environment Programme
U.S. EPA	United States Environmental Protection Agency
WtE	Waste-to-Energy

Acknowledgements

The United States Environmental Protection Agency's (U.S. EPA's) Office of Resource Conservation and Recovery developed the Best Practices for Solid Waste Management: A Guide for Decision-Makers in Developing Countries (Guide) based on U.S. EPA's long history of supporting solid waste management practices and policies that protect human health and the environment.

U.S. EPA received content development, graphical, editorial, and production support from Abt Associates under contract EP-W-10-054, with considerable support from independent consultant Nimmi Damodaran.

The following individuals and organizations supported the development of the Guide:

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United Nations Environment Programme (Sandra Mazo-Nix)

International Solid Waste Association (Aditi Ramola)

C40 Cities (Ricardo Cepeda)

The World Bank (Silpa Kaza)

Swedish Environmental Protection Agency (Åsa Bergèrus Rensvik)

The Energy and Resources Institute (Sourabh Manuja)

Brazilian Association of Sanitation & Special Waste Companies (Gabriela Otero)

Center for Clean Air Policy (Gerardo Canales)

Center for Circular Economy and Climate Change (Goran Vujic)

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1 INTRODUCTION

Section 1

Introduction

Solid waste management is a local issue with global implications. As the world's population continues to grow, so does the amount of waste being produced. In 2015, the world generated 2 billion metric tons of solid waste. This number is expected to grow to 3.4 billion metric tons by 2050. In low-income countries, the amount of waste is expected to increase by more than three times by 2050 (Kaza et al. 2018). As waste generation increases, so does the importance of having an effective solid waste management system in place. However, cities and local governments face many challenges when it comes to properly managing their solid waste. As a result, it is estimated that at least 2 billion people live in areas that lack waste collection and rely on uncontrolled dumpsites (UNEP and ISWA 2015). Inadequate solid waste management systems present serious risks to human health, the environment, and livelihoods in many cities.

The **Best Practices for Solid Waste Management: A Guide for Decision-Makers in Developing Countries** (Guide) is focused on best practices for solid waste management in medium and large urban centers in developing countries (generally referred to as "cities" in the Guide), because they face the most substantial solid waste management challenges. Given their waste generation projections, these challenges will only become more acute in the future and decision-makers have the opportunity to take important and effective action. Portions of the Guide might also be applicable to rural towns, villages, or other small jurisdictions. The Guide's primary audience is state and local government authorities in these cities. These authorities typically include decision-makers, policymakers, and agency staff involved in solid waste management. Aspects of the Guide might be applicable to other stakeholders such as nongovernmental organizations, private sector actors, or residents.

The Guide is not intended to be a step-by-step implementation manual, but it does highlight many such manuals and other resources that local authorities and decision-makers can refer to for more detailed technical guidance. Approaches that may be successful in one city or region may not function everywhere, so the Guide presents decision-makers with the information and resources to improve solid waste management within the context of their given situation. The following page summarizes the Guide's sections.

Sections of the Guide

Understanding the need for solid waste management. Section 2 describes the benefits of improved solid waste management and identifies several primary challenges that developing countries face when dealing with solid waste.

Approaches. Section 3 introduces the solid waste management hierarchy and explains its rationale.

Stakeholder engagement. Section 4 describes best practices for identifying and engaging with stakeholders to support effective solid waste management systems.

Planning systems. Section 5 introduces key concepts associated with planning effective solid waste management systems.

Economic considerations. Section 6 describes several ways in which cities can pay for solid waste management programs and projects, including using internal revenue sources and accessing external financing.

Waste characterization. Section 7 includes information on what categories to consider, what information to collect, and how to ensure data quality.

Prevention and minimization. Section 8 includes strategies for reducing waste from diverse sources.

Separation, collection, and transportation. Section 9 includes information on primary (e.g., from households) and secondary collection using transfer stations (also called waste collection centers; these are decentralized facilities where waste is sorted and transferred).

Organic waste management. Section 10 includes information on the types of treatment (e.g., composting and anaerobic digestion) and policies and programs to support diversion strategies.

Recycling. Section 11 includes descriptions of types of recyclable materials, strategies for promoting recycling, and infrastructure and policy considerations.

Dumpsite management. Section 12 includes approaches to upgrade from open to controlled dumpsites and ultimately close dumpsites.

Sanitary landfills. Section 13 includes approaches and keys aspects of planning, designing, operating, and closing sanitary landfills. It also addresses landfill gas energy recovery and use, a key aspect of sanitary landfills.

Energy recovery. Section 14 profiles information on waste combustion and energy generation.

Bibliography

Appendix A – Summary of Key Resources

Appendix B – Region-Specific Resources for Solid Waste Management

Appendix C – Public Engagement/ Communications Tools

You can use the home icon to access this "Sections of the Guide" page at any time.

You can also use the back icon to return to your most recently viewed page.

Key Features of the Guide

Case Studies
Case studies provide more detailed descriptions of projects or activities from cities worldwide

Case in Point
Case in point boxes provide brief examples from cities across the world

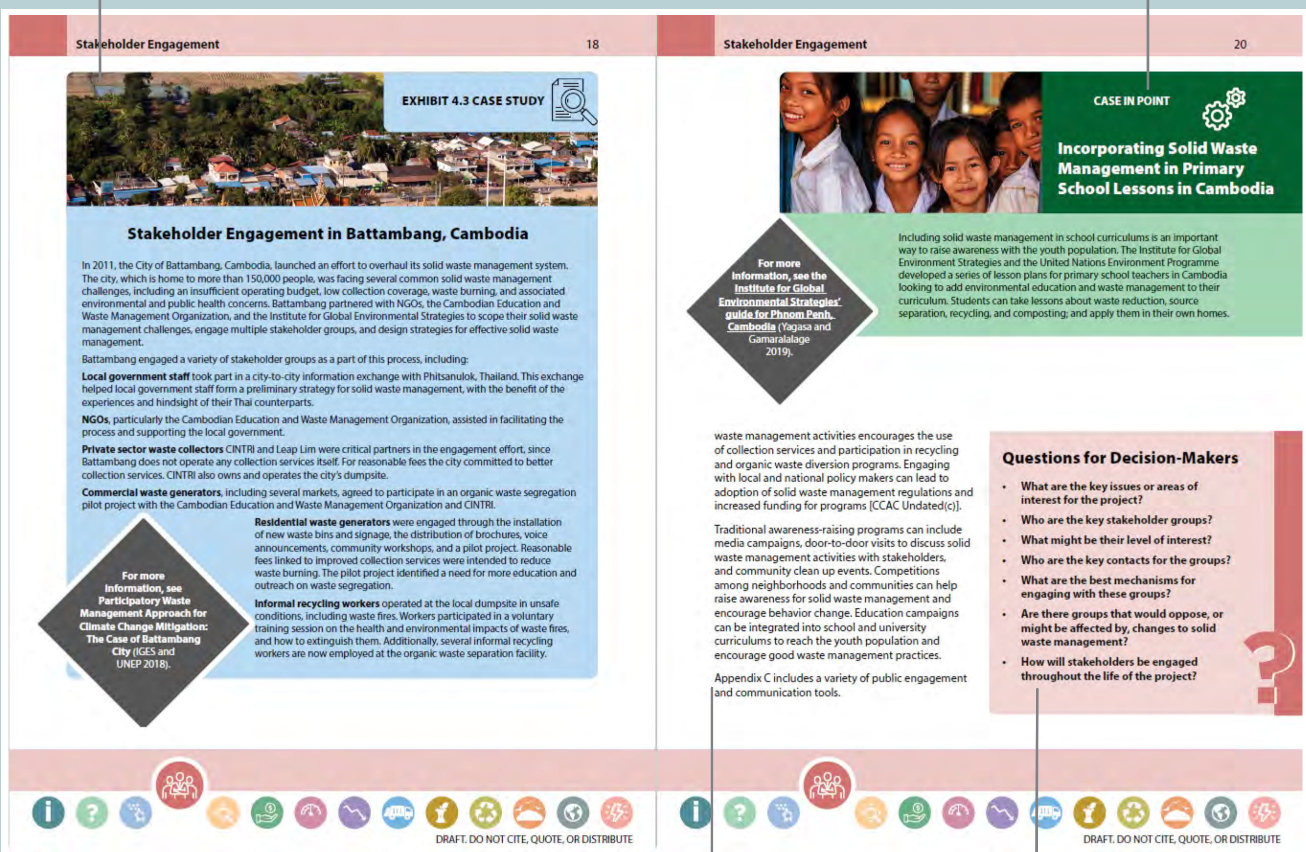
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EXHIBIT 4.3 CASE STUDY

Stakeholder Engagement in Battambang, Cambodia

In 2011, the City of Battambang, Cambodia, launched an effort to overhaul its solid waste management system. The city, which is home to more than 150,000 people, was facing several common solid waste management challenges, including an insufficient operating budget, low collection coverage, waste burning, and associated environmental and public health concerns. Battambang partnered with NGOs, the Cambodian Education and Waste Management Organization, and the Institute for Global Environmental Strategies to scope their solid waste management challenges, engage multiple stakeholder groups, and design strategies for effective solid waste management.

Battambang engaged a variety of stakeholder groups as a part of this process, including:

Local government staff took part in a city-to-city information exchange with Phitsanulok, Thailand. This exchange helped local government staff form a preliminary strategy for solid waste management, with the benefit of the experiences and hindsight of their Thai counterparts.

NGOs, particularly the Cambodian Education and Waste Management Organization, assisted in facilitating the process and supporting the local government.

Private sector waste collectors CINTRI and Leap Lim were critical partners in the engagement effort, since Battambang does not operate any collection services itself. For reasonable fees the city committed to better collection services. CINTRI also owns and operates the city's dumpsite.

Commercial waste generators, including several markets, agreed to participate in an organic waste segregation pilot project with the Cambodian Education and Waste Management Organization and CINTRI.

Residential waste generators were engaged through the installation of new waste bins and signage, the distribution of brochures, voice announcements, community workshops, and a pilot project. Reasonable fees linked to improved collection services were intended to reduce waste burning. The pilot project identified a need for more education and outreach on waste segregation.

Informal recycling workers operated at the local dumpsite in unsafe conditions, including waste fires. Workers participated in a voluntary training session on the health and environmental impacts of waste fires, and how to extinguish them. Additionally, several informal recycling workers are now employed at the organic waste separation facility.

For more information, see Participatory Waste Management Approach for Climate Change Mitigation: The Case of Battambang City (IGES and UNEP 2018).

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CASE IN POINT

Incorporating Solid Waste Management in Primary School Lessons in Cambodia

Including solid waste management in school curriculums is an important way to raise awareness with the youth population. The Institute for Global Environment Strategies and the United Nations Environment Programme developed a series of lesson plans for primary school teachers in Cambodia looking to add environmental education and waste management to their curriculum. Students can take lessons about waste reduction, source separation, recycling, and composting; and apply them in their own homes.

For more information, see the Institute for Global Environmental Strategies' guide for Phnom Penh, Cambodia (Yagasa and Gamaralalage 2019).

waste management activities encourages the use of collection services and participation in recycling and organic waste diversion programs. Engaging with local and national policy makers can lead to adoption of solid waste management regulations and increased funding for programs [CCAC Undated(c)].

Traditional awareness-raising programs can include media campaigns, door-to-door visits to discuss solid waste management activities with stakeholders, and community clean up events. Competitions among neighborhoods and communities can help raise awareness for solid waste management and encourage behavior change. Education campaigns can be integrated into school and university curriculums to reach the youth population and encourage good waste management practices.

Appendix C includes a variety of public engagement and communication tools.

Questions for Decision-Makers

- **What are the key issues or areas of interest for the project?**
- **Who are the key stakeholder groups?**
- **What might be their level of interest?**
- **Who are the key contacts for the groups?**
- **What are the best mechanisms for engaging with these groups?**
- **Are there groups that would oppose, or might be affected by, changes to solid waste management?**
- **How will stakeholders be engaged throughout the life of the project?**

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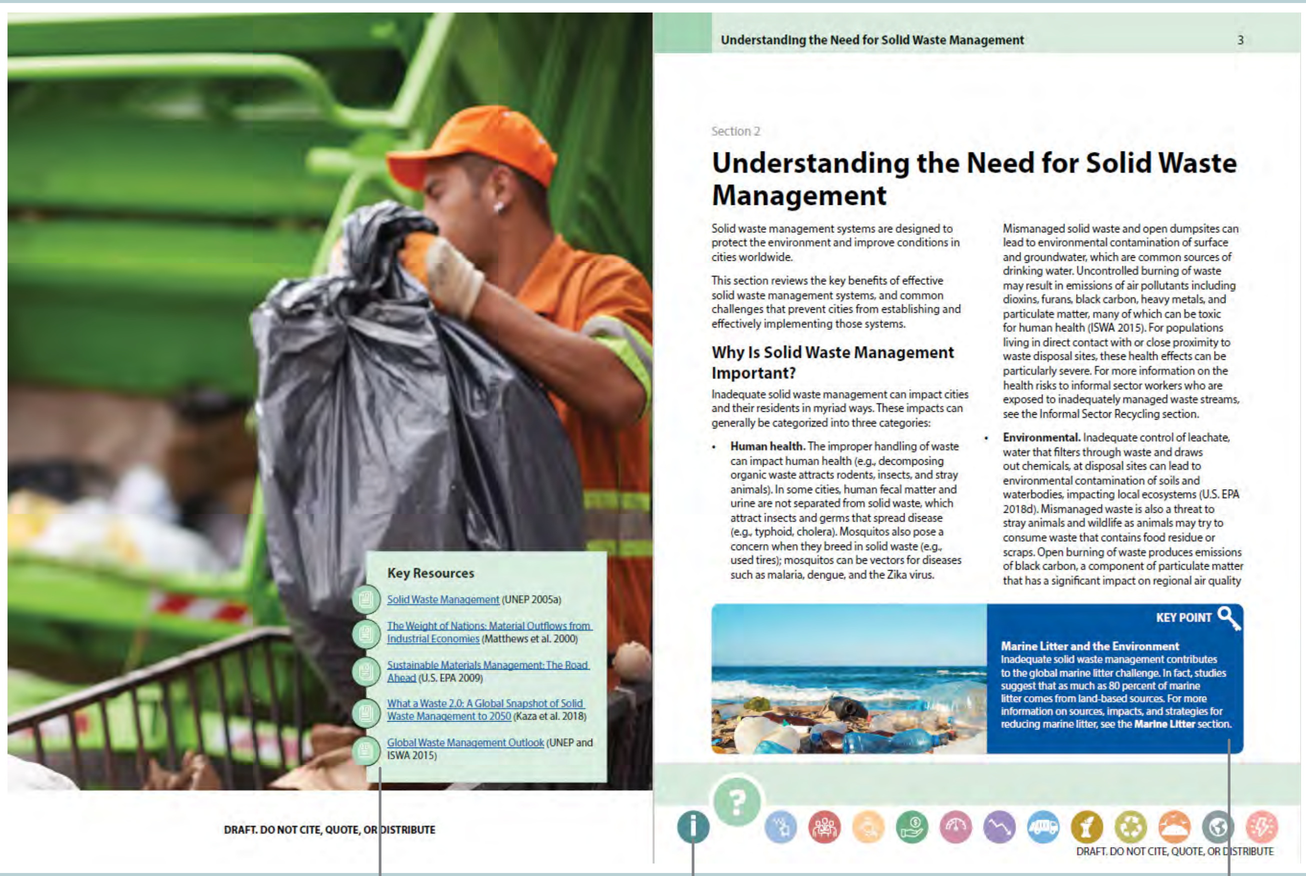
Best Practices
Best practices highlight solid waste management options and benefits

Questions
Questions for decision-makers to consider when evaluating options for improving solid waste management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Section 2

Understanding the Need for Solid Waste Management

Solid waste management systems are designed to protect the environment and improve conditions in cities worldwide.

This section reviews the key benefits of effective solid waste management systems, and common challenges that prevent cities from establishing and effectively implementing those systems.

Why Is Solid Waste Management Important?

Inadequate solid waste management can impact cities and their residents in myriad ways. These impacts can generally be categorized into three categories:

- Human health. The improper handling of waste can impact human health (e.g., decomposing organic waste attracts rodents, insects, and stray animals). In some cities, human fecal matter and urine are not separated from solid waste, which attract insects and germs that spread disease (e.g., typhoid, cholera). Mosquitos also pose a concern when they breed in solid waste (e.g., used tires); mosquitos can be vectors for diseases such as malaria, dengue, and the Zika virus.

Mismanaged solid waste and open dumpsites can lead to environmental contamination of surface and groundwater, which are common sources of drinking water. Uncontrolled burning of waste may result in emissions of air pollutants including dioxins, furans, black carbon, heavy metals, and particulate matter, many of which can be toxic for human health (ISWA 2015). For populations living in direct contact with or close proximity to waste disposal sites, these health effects can be particularly severe. For more information on the health risks to informal sector workers who are exposed to inadequately managed waste streams, see the Informal Sector Recycling section.

- Environmental. Inadequate control of leachate, water that filters through waste and draws out chemicals, at disposal sites can lead to environmental contamination of soils and waterbodies, impacting local ecosystems (U.S. EPA 2018d). Mismanaged waste is also a threat to stray animals and wildlife as animals may try to consume waste that contains food residue or scraps. Open burning of waste produces emissions of black carbon, a component of particulate matter that has a significant impact on regional air quality

KEY POINT

Marine Litter and the Environment

Inadequate solid waste management contributes to the global marine litter challenge. In fact, studies suggest that as much as 80 percent of marine litter comes from land-based sources. For more information on sources, impacts, and strategies for reducing marine litter, see the Marine Litter section.

Key Resources

Solid Waste Management (UNEP 2005a)

The Weight of Nations: Material Outflows from Industrial Economies (Matthews et al. 2000)

Sustainable Materials Management: The Road Ahead (U.S. EPA 2009)

What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050 (Kaza et al. 2018)

Global Waste Management Outlook (UNEP and ISWA 2015)

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Key Resources
Key resource boxes identify useful guidance materials, tools, and studies

Navigation Icons
Clickable icons facilitate easy navigation between topics

Key Point Boxes
Key Point boxes highlight important concepts, issues, or other details to consider when evaluating opportunities for improving solid waste management

2 UNDERSTANDING THE NEED FOR SOLID WASTE MANAGEMENT

Key Resources

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- Sustainable Materials Management: The Road Ahead (U.S. EPA 2009)
- What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050 (Kaza et al. 2018)
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Section 2

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and global climate. Waste disposal sites release methane, which contributes to the formation of ground-level ozone. In addition, methane is a greenhouse gas that contributes to climate change. For more information on the air quality and climate change impacts of inadequate solid waste management, see the Climate and Clean Air Coalition's *Municipal Solid Waste Initiative* website).

- **Socioeconomic.** Inadequate solid waste management can be costly, both in terms of direct expenses and indirect costs. Mismanaged solid waste systems are a missed opportunity for economic growth, including increased property values and tourism benefits from having clean streets and beaches. Programs reducing waste can lead to cost savings in transportation and fuel costs, and cost recovery if implemented correctly. Improved solid waste management can especially benefit highly vulnerable populations through cost savings on public health systems by preventing respiratory issues, skin diseases, and other health care concerns associated with inadequate solid waste management (ISWA 2015). For more information on waste minimization, see the *Prevention and Minimization* section.

Taking action to improve solid waste management can help mitigate these impacts. The sections of this document that describe best practices for solid waste management provide more details on the specific benefits of each best practice.

Common Challenges

Cities recognize the many health, environmental, and other concerns associated with inadequate solid waste management; however, they face many challenges in properly managing this waste. Common challenges include:

- **Limited financial resources and capacity**. Many cities have limited capacity for sustainably funding infrastructure or operations. Cities are often responsible for implementation but do not have the finances or financial expertise and struggle with investment costs, the upkeep of facilities, establishing a sufficient budget for solid waste projects, or rising costs and inadequate revenues as the volume of waste continues to increase. Prioritizing solid waste management, researching cost-cutting strategies, incorporating pay-as-you-throw programs or taxes, and partnering with international investment organizations are all options for funding a viable solid waste program. Although some programs, taxes, or fees will face resistance when introduced, finding a sustained source of funding for solid waste management is an integral part of a successful program. Other economic considerations for solid waste management are discussed in the *Economic Considerations* section.

- **Limited access to and technical knowledge of equipment**. Equipment to handle solid waste

Exhibit 2.1. Challenges to Proper Solid Waste Management

often needs to be imported, and operators may not have the technical knowledge or resources for proper and consistent maintenance. If the equipment is not designed for local conditions, this incompatibility can add further challenges because frequent repairs may be needed, and spare parts may be difficult to find. In tropical areas, local conditions such as humidity and heat can negatively affect equipment, leading to frequent repairs. In many cases, there are multiple equipment options, some of which may be better suited to local conditions. Some of these options are presented in relevant sections in this Guide. An analysis of the waste stream and available resources can provide guidance on the most appropriate option.

- **Limited technical expertise and awareness of best practices.** Local governments often lack the expertise needed to evaluate technologies or solutions in order to identify the most appropriate ones for their situation. Difficult situations can arise when private companies contract with cities to provide a technology or implement a project but abandon the project if the city cannot meet the terms of the contract. For example, many waste treatment project contracts include requirements that the city guarantee a clean or consistent feedstock. Private companies can and will abandon the work if the city fails to meet these requirements. Cities do not always anticipate these challenges, and projects can fail as a result. Decision-makers and staff at the local level are often not aware of best practices that other cities in similar situations have implemented successfully. Technical knowledge and awareness of best practices can be improved by participating in domestic and international exchanges such as conferences and webinars organized by the International Solid Waste Association. Centers of excellence – such as those identified in the text box to the right – can also be valuable resources for disseminating lessons and experiences.

- **Limited staff capacity**. Many cities lack sufficient staff who are dedicated to addressing solid waste management issues. These staff are often focused on addressing immediate waste emergencies and have limited time or capacity to engage in longer-term planning and strategy development.

- **Political turnover**. Changes in administrations can result in projects being shut down or radically altered by incoming officials and key staff reassignments on large capital projects, including solid waste management projects. As a result, many project champions who possess considerable technical expertise are not available to see projects through to completion. Solid waste management legislation, either national or subnational, which establishes long-term, sustainable systems that continue across administrations, can help overcome this barrier. Maintaining staff continuity on solid waste management projects and operations can also help minimize these disruptions.

- **Lack of planning and evaluation** at both national and municipal levels can negatively affect the success of a solid waste management system. National frameworks or regulations are important to facilitate long-term planning; establish national standards; and provide incentives for programs to reduce, recycle, or compost their waste. Planning at the municipal level where implementation occurs is often overlooked and can create challenges later. This is especially prevalent when there are unplanned disruptions such as natural disasters. Creating a national and local plan, which includes a monitoring and verification system, will help create a stable solid waste management system. The *Planning Systems* section provides additional details on the importance of planning and identifies key steps.

- **Limited or lack of vertical and horizontal government coordination.** Solid waste management usually falls under the jurisdiction of multiple ministries or agencies at various levels of government. For example, the government agencies responsible for the environment, urban and housing development, or agriculture may all be involved at different parts of the solid waste management system, but may not have formal frameworks for collaboration. In addition, local governments are responsible for the implementation of national regulations, and national governments can play a significant role in creating enabling environments for successful local projects. A mechanism that enables coordination between agencies or departments and between the layers of government can assist in creating a holistic system.

- **Difficult working conditions.** Solid waste management workers in developing countries may be underpaid and undertrained (UNEP 2005a). Without proper training and personal protective equipment, these workers are at risk of injury or disease. Studies show that a high percentage of workers who handle waste, and individuals who live near disposal sites, are at risk of being infected with worms or parasites (UNEP 2005a). Difficult working conditions also result in a lack of motivation for workers and low employee retention rates.
- **Limited or lack of communications with relevant stakeholders,** including residents, can lead to illegal dumping, misuse and damage of containers, resistance to service fees, improper waste segregation, among other things. Coordinated communications and outreach campaigns can help ensure that relevant stakeholder groups are informed and equipped to comply with local solid waste management requirements. For additional information on best practices for identifying and incorporating stakeholders into solid waste management planning, see the *Stakeholder Engagement* section.

  The informal sector is an important stakeholder group to consider and include during specific steps while planning a solid waste management program. In general, the informal sector consists of individuals, groups, and small businesses that perform informal waste services involving the collection and sale of recyclables, usually through middlemen or intermediaries (Aparcana 2017). Workers earn income by selling the recyclables they collect to a network of dealers and recycling industries that work within the formal private sector (Aparcana 2017, Wilson et al. 2009); in other cases, workers may sell to other informal sector workers that reuse the material as input in another

  process or product (e.g., use of used parts to repair equipment). This sector can play a large role in separating materials and determining what waste will be collected. For challenges of and suggestions on working with the informal sector, see the *Informal Sector Recycling* section.

- **Limited available land**. As urban areas and populations continue to grow, the amount of available space for solid waste facilities, local collection locations, and transfer stations decreases. There may not be space, the available parcels may be too expensive, or local residents may prevent facilities from being developed due to fears of smell depreciating their living conditions or property prices. However, siting these facilities at a distance from cities, where land is more available and less expensive, creates a new set of challenges because hauling waste long distances can be time-consuming and expensive. Solid waste managers can work with local and regional leaders to create a solid waste management plan that emphasizes the importance of route and city planning. Diversion or separation programs will also play a large role in reducing the amount of waste that needs to be collected at one time.

Transfer stations and other options for collection and storage are discussed in the *Separation, Collection, and Transportation* section.

- **Climatologic, geographic, and topographic conditions** all influence the availability and cost of equipment, the feasibility of technologies, operating costs, and other aspects of solid waste management. For instance, cities in tropical zones might adapt solid waste management strategies to account for higher temperatures and faster organic waste decomposition rates than cities in cooler climates. Geographic and topographic features can pose challenges for solid waste management as well. Islands, in particular, face significant challenges due to limited space for waste disposal, as well as limited access to and capacity for recycling. Cities in hilly areas may need to design disposal sites that are resilient to slope failure. Appendix B provides several key resources for understanding best practices for managing solid waste in specific global regions; these resources are useful for identifying region-specific conditions that are relevant for solid waste management planning.
- **Cultural norms**. Cultural preferences and tendencies can complicate solid waste management efforts. For example, increasing wealth and lower prices for goods have led to a dramatic growth in material consumption and waste generation worldwide. Solid waste managers are faced with the implications of these trends. Addressing cultural norms during solid waste management planning requires a coordinated stakeholder engagement approach. More information on best practices for stakeholder engagement is available in the *Stakeholder Engagement* section.

KEY POINT

Cities Can Leverage Centers of Excellence to Build Capacity

Cities are exploring various approaches to address limitations related to technical capacity and knowledge. One solution cities are implementing is accessing resources and information available through "centers of excellence." These are organizations or partnerships dedicated to sharing information, providing training, and facilitating exchanges of best practices related to solid waste management.

Examples of waste management centers of excellence include:

Municipal Solid Waste Knowledge Platform: Tools: This resource is maintained by the Climate and Clean Air Coalition Waste Initiative to exchange information and resources on best practices [CCAC Undated(b)].

Solid Waste Institute for Sustainability: This institute is based at the University of Texas at Arlington, and provides capacity-building support and training sessions to help cities improve solid waste management (University of Texas at Arlington 2015).

Center of Excellence for Circular Economy and Climate Change: This center is based in Novi Sad, Serbia, and provides solid waste-related information exchange support and technical expertise for cities in Southeast Europe, the Middle East, and Central Asia (CECC 2020).

Be'ah Environmental Centre of Excellence: This center provides training and expert support for cities in Oman to help them improve waste management (be'ah 2017b).

The Energy and Resources Institute Center for Waste Management: This center provides support for cities in India through technical assistance, workshops, and networking (TERI 2020b).

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3 APPROACHES

Key Resources

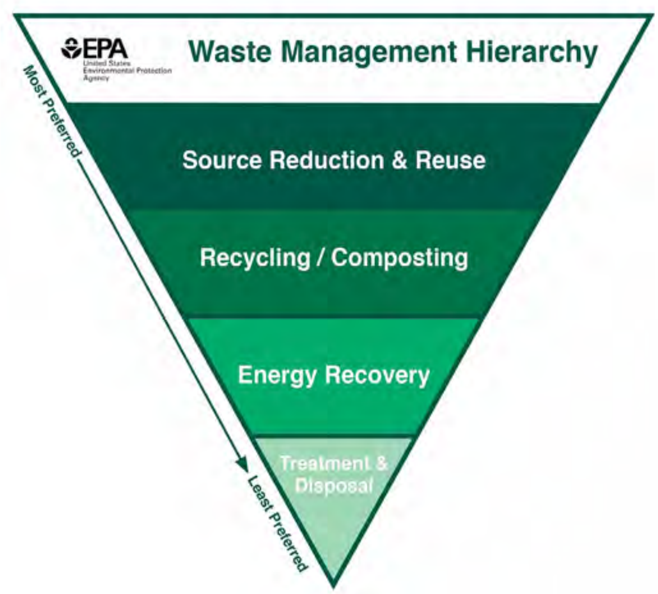
[Sustainable Materials Management: Non-Hazardous Materials and Waste Management Hierarchy](#) (U.S. EPA 2017)

[Sector Environmental Guideline: Solid Waste](#) (USAID 2018)

Section 3

Approaches

Exhibit 3.1. Waste Management Hierarchy



No single solid waste management approach is suitable for managing all materials and waste streams in all circumstances. Local governments should work to create a plan that meets the specific needs and conditions of their area. The United States Environmental Protection Agency developed a solid waste management hierarchy (Exhibit 3.1) in recognition of this reality. This hierarchy provides a general ranking system for the various solid waste management strategies from most to least environmentally preferable; and places emphasis on reducing, reusing, and recycling (U.S. EPA 2017f).

This section briefly describes each management strategy found in the solid waste management hierarchy. More detailed information can be found in later sections, which are linked in each description.

Why Is a Hierarchy of Solid Waste Management Approaches Important?

A solid waste management hierarchy outlines the most environmentally friendly steps to take before disposing of waste in a dumpsite or landfill. The first and most preferred step in the hierarchy, source reduction and reuse, focuses on preventing waste from being generated. When waste is reduced or reused at the source, fewer raw materials are needed and less waste needs to be collected, transported, and disposed of. This reduction in extractive processes leads to both environmental benefits and cost savings throughout the life of a product. For waste that cannot be reduced or reused at the source, recycling or composting is the next best option. Recycling or composting produces environmental benefits and cost savings similar to source reduction and reuse, but requires upfront investment costs to put an effective recycling or composting program in place. Source reduction and recycling strategies both help to reduce the amount of waste that might ultimately enter the environment, including waterbodies and marine litter. Energy recovery can be considered for waste that is not recyclable or compostable. Energy recovery reduces the amount of waste that ultimately ends up in landfills and dumpsites, and offsets the need for fossil fuel use. However, energy recovery from waste can result in air pollution emissions and require significant investment and operational costs.

Elements of the Solid Waste Management Hierarchy

Source Reduction and Reuse

Source reduction, also known as waste prevention, refers to reducing the amount of waste generated. Reducing waste at the source is the most environmentally preferred strategy (U.S. EPA 2017f). Individuals can reduce the amount of waste they generate by purchasing long-lasting and reusable products, or seeking out products that have been designed with waste reduction in mind. The *Prevention and Minimization* section discusses source reduction and reuse further.

Recycling and Organic Waste Management

Recycling is a series of activities that includes collecting used, reused, or unused items that would otherwise be considered waste; sorting and processing the recyclable products into raw materials; and remanufacturing the recycled raw materials into new products (U.S. EPA 2017f). The informal sector is a key participant in the recycling system in many places worldwide. The *Recycling* section explains the benefits and challenges of recycling, and best practices in setting up a recycling program, including engaging with the informal sector.

Organic waste management deals with the diversion and treatment of organic waste through composting and anaerobic digestion (AD). Compost is organic material that can be added to soil to help plants grow. AD is a process that generates biogas – a renewable energy source – using organic waste as a feedstock. Composting or using AD for food scraps, yard trimming, and other organic materials keeps these materials out of landfills, where they take up space and release methane, a potent greenhouse gas. The *Organic Waste Management* section covers different options from small-scale composting to large-scale AD, and best practices for separating this waste from the general waste stream.

Energy Recovery

Energy recovery is the conversion of non-recyclable materials into useable heat, electricity, or fuel through a variety of processes. This process is often called waste-to-energy. Converting non-recyclable materials into electricity and heat generates an energy source and reduces carbon emissions by offsetting the need for energy from fossil sources, and reduces methane generation from landfills (U.S. EPA 2017f).

Waste-to-energy plants have a high upfront investment cost and are costly to operate and maintain. Additionally, toxic emissions from such units

have to be controlled. When coupled with effective end-of-pipe air pollution controls (i.e., controls placed on a facility that treats gases before they enter the environment) and waste disposal techniques, these plants can potentially reduce both waste volumes and greenhouse gas emissions (USAID 2018). However, adequate financing plans and effective pollution controls are key factors to consider before planning a waste-to-energy facility as a viable solid waste management option. The *Energy Recovery* section provides more information on different types of energy recovery technologies and key prerequisites to consider related to these management approaches.

Treatment and Disposal

Prior to disposal, treatment can help reduce the volume and toxicity of waste. Treatments can be physical (e.g., shredding), chemical (e.g., incineration), or biological (e.g., AD; U.S. EPA 2017f). Landfills are an important component of an integrated solid waste management system. Waste that cannot be prevented or recycled should be disposed of in properly designed, constructed, and managed landfills, where it is safely contained to limit its environmental impacts (U.S. EPA 2002a). Methane gas, a byproduct of decomposing waste, can be collected and used as fuel to generate energy. After a landfill is capped, the land may be used for other purposes such as recreational sites. The *Dumpsite Management* and *Sanitary Landfills* sections discuss strategies for improving or closing an open dumpsite and setting up and operating a landfill, respectively.

4 STAKEHOLDER ENGAGEMENT

Key Resources

- Public Participation Guide (U.S. EPA 2017d)
- Handbook on Communication and Engagement for Solid Waste Management (ABRELPE and CCAC 2017)
- Decision-Maker's Guide to Solid Waste Management, Volume II (U.S. EPA 1995)

Section 4

Stakeholder Engagement

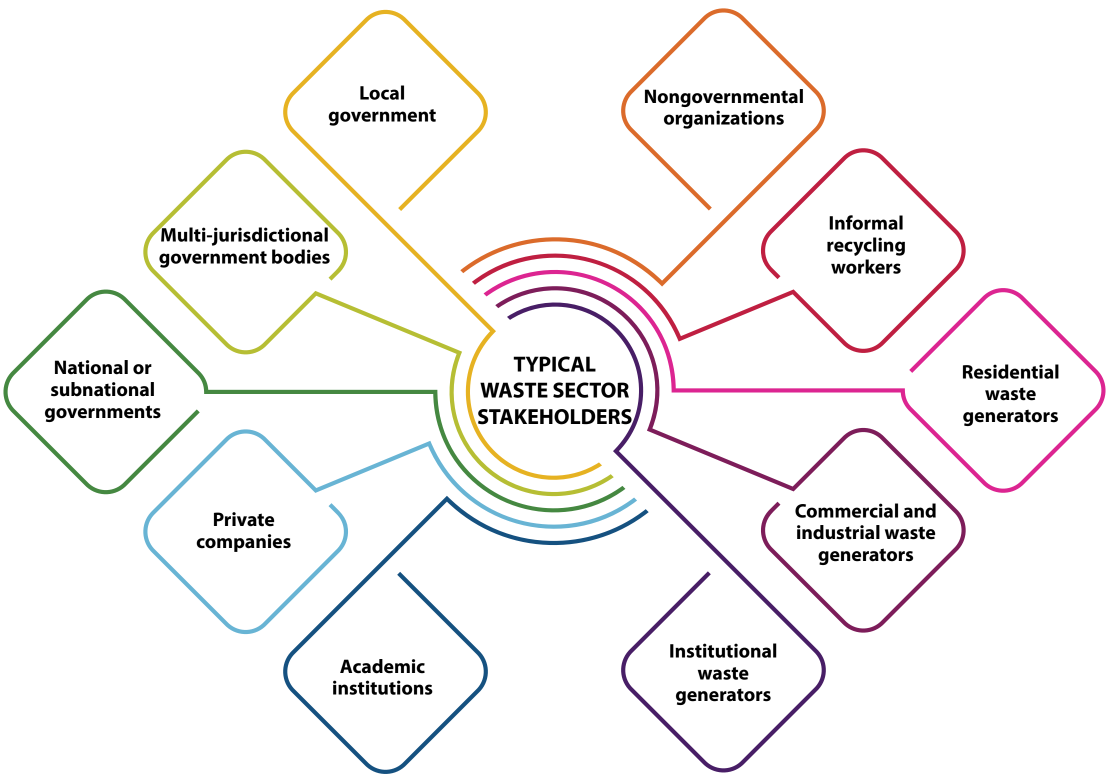
Stakeholder engagement is the process of building relationships with residents, interest groups, and other impacted entities in order to gain support for solid waste management policies, programs, and service issues. Working with stakeholders helps create a robust solid waste management system, protect the environment, and make cities better places to live.

This section provides information on the advantages of actively engaging with stakeholders, and best practices for identifying stakeholders and incorporating their feedback into solid waste management planning. Exhibit 4.1 introduces typical waste sector actors that play a role in most cities.

Why Involve Stakeholders?

Cities have found it necessary to engage the public throughout the planning process to create a robust solid waste management program and maintain long-term support for its operation. Operating a solid waste management program economically and efficiently requires significant cooperation from waste generators (e.g., individual residents and businesses), waste handlers, the informal sector, and all other individuals and organizations impacted by the management of solid waste. To maintain long-term program support, cities have found that these groups need to be continuously engaged in decision-making and informed about policies, programs, and projects.

Exhibit 4.1. Typical Waste Sector Stakeholders



Stakeholder involvement in the waste sector should follow four common principles of stakeholder engagement:

- **Integrity**. Transparent and clear purpose and scope.
- **Inclusiveness.** Accessible to all stakeholders whose full range of values and perspectives are sought.
- **Dialogue**. Open and genuine discussion supported by timely and accurate information.
- **Influence.** Input reflected in outcomes**.**

Best Practices

When planning for a solid waste management program, stakeholder engagement encompasses various local government entities and possible activities. Cities can share information; consult stakeholders through various processes; and, in some instances, encourage active participation in government decision-making processes. Effective stakeholder engagement allows cities to tap into diverse solid waste management perspectives to improve the quality of decision-making. It also enables residents to better understand local government processes; and strengthens their capacity to participate in deliberative processes by building confidence, skills, knowledge, and experience. Cities can use the following steps as a guide to plan a public participation program.

Getting Organized

Before reaching out to stakeholders, cities have found it helpful to first gather information from relevant government entities that are involved in the applicable solid waste management process. This review may include waste management departments, public works departments, and project finance departments. It is important that department staff be familiar with the laws and targets already implemented in that city. This process will allow them to understand the history behind the current solid waste program, assess possibilities, identify and commit resources, and know where public input is possible. Finally, it is essential to ensure that there is political will for these efforts (e.g., support from current and potential future elected officials).

Selecting the Level of Public Participation

Cities can integrate stakeholders into the decision-making process through different activities based on the program's goal. The spectrum of stakeholder engagement is generally categorized into three types of activities:

- **Inform.** Decisions have already been made or action is required. There is a need to ensure that affected stakeholders are aware of the information.
- **Consult**. Input, feedback, or advice from the stakeholders is required before part of the project or decision is finalized.
- **Actively involve**. Specific stakeholder groups or residents are engaged to work through the issues and develop solutions.

Selecting the type of stakeholder engagement will help local authorities and decision-makers select the tools and techniques that can be used since no single approach will suit every issue. Some techniques are designed specifically to share information or elicit views and opinions, while others aim to effectively involve stakeholders and residents in decision-making. The most appropriate stakeholder engagement technique is determined by the issue, the desired objectives, and the available resources. It is a best practice to design stakeholder engagement techniques in collaboration with local organizations that understand the issues pertaining to the area and the local residents.

Identifying Stakeholder Roles

Recognizing residents as a valuable resource unleashes creativity and acknowledges collaboration as the primary catalyst to promote local progress. Cities have found it advisable to clearly designate roles and responsibilities of the participating parties to ensure accountability and ownership (of the process). Governments make policy decisions that direct the implementation

CASE IN POINT

Engaging with the Informal Sector in Peru

For more information, visit *Ciudad Saludable's website* (Ciudad Saludable Undated).

Ciudad Saludable is a Peru-based, nonprofit organization that aims to improve living conditions of informal sector workers by creating efficient solid waste management systems. A key component of their business model is including all stakeholders throughout the process. The organization's model uses microenterprises that produce compost and other marketable byproducts. The microenterprises create a large network of small businesses that employ 1,500 informal sector workers.

Ciudad Saludable has created awareness in Latin America about the working conditions of informal sector workers. The organization has also helped create new legislative frameworks that facilitate dialogue at national and local levels, and emphasize education and knowledge sharing.

Ciudad Saludable reaches an estimated 30 percent of the Peruvian population and estimates that they have improved the lives of over 6 million people living in urban and rural areas (Skoll 2006). The *Informal Recycling* Section provides examples to the benefits and challenges of engaging the informal sector.

of solid waste management programs, but the stakeholders listed in Exhibit 4.2 all participate in the full waste management system in some way (UNEP 2005a).

Exhibit 4.3 presents an example of how one municipality in Cambodia engaged a wide range of stakeholders as part of a comprehensive effort to improve solid waste management.

Integrating Stakeholder Input into the Decision-Making Process

Many cities have found it important to share plans for proposed changes to their solid waste programs with the public and engage with stakeholders to solicit feedback. It is a best practice to allow for public participation in the evaluation of plans and strategies, and ensure that there is a method of communications and a point of contact within the government agency that is leading the effort with whom stakeholders can work. Stakeholders can participate digitally using a public platform or group email list, or through in-person meetings such as open meetings or roundtables.

Exhibit 4.4 presents an example of integrating stakeholder input into the decision-making process in Cebu City, Philippines.

Awareness and Education

A key aspect of solid waste management is continuously communicating with and educating stakeholders throughout the project's life, not only during select stages of project development. For example, informing waste generators about solid waste management activities encourages the use of collection services and participation in recycling and organic waste diversion programs. Engaging with local and national policy makers can lead to adoption of solid waste management regulations and increased funding for programs [CCAC Undated(c)].

Traditional awareness-raising programs can include media campaigns, door-to-door visits to discuss solid waste management activities with stakeholders,

CASE IN POINT

Incorporating Solid Waste Management in Primary School Lessons in Cambodia

For more information, see the ***Institute for Global Environmental Strategies' guide for Phnom Penh, Cambodia*** (Yagasa and Gamaralalage 2019).

Including solid waste management in school curriculums is an important way to raise awareness with the youth population. The Institute for Global Environment Strategies and the United Nations Environment Programme developed a series of lesson plans for primary school teachers in Cambodia looking to add environmental education and waste management to their curriculum. Students can take lessons about waste reduction, source separation, recycling, and composting; and apply them in their own homes.

and community clean up events. Competitions among neighborhoods and communities can help raise awareness for solid waste management and encourage behavior change. Education campaigns can be integrated into school and university curriculums to reach the youth population and encourage good waste management practices.

Appendix C includes a variety of public engagement and communication tools.

Questions for Decision-Makers

- What are the key issues or areas of interest for the project?
- Who are the key stakeholder groups?
- What might be their level of interest?
- Who are the key contacts for the groups?
- What are the best mechanisms for engaging with these groups?
- Are there groups that would oppose, or might be affected by, changes to solid waste management?
- How will stakeholders be engaged throughout the life of the project?

Exhibit 4.2. Stakeholder Roles (adapted from UNEP 2005a)

Local government
Local governments plan and implement solid waste management programs. Multiple departments are often involved: public works departments collect and dispose of waste; public health and sanitation departments inspect and enforce sanitation standards; environmental protection departments monitor air and water quality, and pollution control measures; parks or agriculture departments can use compost that is a product of organic waste treatment; and financing departments allocate funds available for solid waste management activities.

Multi-jurisdictional government bodies (metropolitan planning entities)
Bodies that bring together multiple local governments for regional planning purposes are often responsible for larger operations such as landfills, waste-to-energy, anaerobic digesters, or composting facilities. These bodies may collaborate on the siting of new sanitary landfills, transfer stations, and other recycling or treatment facilities. For shared facilities, they would also establish disposal or user fees.

National or subnational governments
National governing bodies establish solid waste management policies and regulations, including waste handling, treatment, and landfilling specifications; public health protection measures; and pollution prevention. They have a role in the inspection and enforcement of treatment and waste facilities. Additionally, they establish regulations and standards for the offtake of waste treatment byproducts, including biogas and electricity.

Private companies
Private sector actors such as waste haulers, construction companies, landfill site operators, material recovery facility operators, and material buyers often contract with the government to perform solid waste management activities. In countries with extended producer responsibility systems in place, the private sector is also responsible for the end-of-life treatment of its products. The *Economic Considerations* section discusses extended producer responsibility in more detail.

Nongovernmental organizations (NGOs)
NGOs representing a variety of interests such as workforce development or safety, environmental protection, economic development, public health, or even specific neighborhoods have a vested interested in solid waste management. These groups can be important allies in planning processes. Foremost, they have an understanding of the local point of view for local authorities to consider in decision-making. These groups can also serve an important role in educating the public on different aspects of solid waste management.

Academic institutions
Local universities often have technical expertise that can support waste characterization or collection activities through scientific data collection and analysis, and can also monitor outcomes of pilot programs.

Informal recycling workers
Informal sector workers collect recyclable and reusable materials from communal waste bins and disposal sites, and frequently work in unsafe conditions. There are many advantages to incorporating informal sector workers into the formal solid waste management system, particularly to reduce social vulnerability and promote gender equality and empowerment for women that comprise much of the sector. See the *Informal Sector Recycling* section for more information.

Residential waste generators
Residential or household waste can make up a large portion of the urban waste stream. However, waste collection and disposal options are often lacking on the periphery of urban areas, which can lead to open dumping and exposure of residents to human health harms. Residents can play an important role in improved waste prevention, minimization, segregation, and collection schemes; and siting waste treatment and disposal facilities. Education and outreach to residents on new waste programs or fees supports better solid waste management overall. In many cases, women manage the collection and separation of household waste. As a best practice, women should be involved in local outreach efforts.

Commercial and industrial waste generators
Several commercial and industrial enterprises generate waste, including offices, medical facilities, hotels, markets, construction sites, industrial operations, and others. These large-scale waste generators, which do not typically rely on the same collection means as residential users, sometimes sort and transport their waste to communal locations (e.g., they may arrange private sector agreements for collection and disposal).

Institutional waste generators
Other organizations that generate waste include government institutions, schools and universities, religious institutions, and hospitals and healthcare facilities. Solid waste management services to these groups vary; some municipalities include these organizations in their service areas, while others require them to contract private waste haulers. Often the decision depends on the type and amount of waste these institutions generate. These groups can also play an important role in education and outreach, encouraging members to practice good waste minimization and segregation.

EXHIBIT 4.3 CASE STUDY

Stakeholder Engagement in Battambang, Cambodia

In 2011, the City of Battambang, Cambodia, launched an effort to overhaul its solid waste management system. The city, which is home to more than 150,000 people, was facing several common solid waste management challenges, including an insufficient operating budget, low collection coverage, waste burning, and associated environmental and public health concerns. Battambang partnered with NGOs, the Cambodian Education and Waste Management Organization, and the Institute for Global Environmental Strategies to scope their solid waste management challenges, engage multiple stakeholder groups, and design strategies for effective solid waste management.

Battambang engaged a variety of key stakeholder groups as a part of this process, including:

Local government staff took part in a city-to-city information exchange with Phitsanulok, Thailand. This exchange helped local government staff form a preliminary strategy for solid waste management, with the benefit of the experiences and hindsight of their Thai counterparts.

NGOs, particularly the Cambodian Education and Waste Management Organization, assisted in facilitating the process and supporting the local government.

Private sector waste collectors CINTRI and Leap Lim were critical partners in the engagement effort, since Battambang does not operate any collection services itself. For reasonable fees the city committed to better collection services. CINTRI also owns and operates the city's dumpsite.

Commercial waste generators, including several markets, agreed to participate in an organic waste segregation pilot project with the Cambodian Education and Waste Management Organization and CINTRI.

Residential waste generators were engaged through the installation of new waste bins and signage, the distribution of brochures, voice announcements, community workshops, and a pilot project. Reasonable fees linked to improved collection services were intended to reduce waste burning. The pilot project identified a need for more education and outreach on waste segregation.

Informal recycling workers operated at the local dumpsite in unsafe conditions, including waste fires. Workers participated in a voluntary training session on the health and environmental impacts of waste fires, and how to extinguish them. Additionally, several informal recycling workers are now employed at the organic waste separation facility.

For more information, see ***Participatory Waste Management Approach for Climate Change Mitigation: The Case of Battambang City*** (IGES and UNEP 2018).

EXHIBIT 4.4 CASE STUDY

The Role of Partnerships in Solid Waste Management in Cebu City, Philippines

In the Philippines, rapid urbanization has strained the country's ability to properly dispose of waste. In Cebu City, the responsibility of waste collection falls to the city government and barangays, the smallest administrative districts in the Philippines. Cebu City collects waste from commercial establishments, institutions, and households on main roads. Barangays are responsible for waste collection within their administrative unit using their own vehicles or those provided by the city. Starting in 2010, Cebu City began implementing legislation to increase waste collection and management.

To increase the effectiveness and participation in such legislation, Cebu City established partnerships with a number of local groups and institutions, which have led to achievements such as:

- **A series of annual competitions through partnerships with businesses and the local media**. One example is the "Best Environmental Barangay Award" that is given to communities with high participation in solid waste management activities.
- **Municipal-wide awareness raising campaigns**. These campaigns involve local NGOs, homeowner's associations, informal sector workers, academic institutions, local enterprises, and the media.
- **Additional solid waste management through public-private partnerships**. Two private ventures have established treatment facilities near the City of Cebu's landfill. One handles plastics recycling and the other handles organic waste, reducing the amount of each that enters the landfill.
- **Community recycling programs through partnerships with local businesses and tenants**. One program in the Ayala Mall has set up an effective recycling program: businesses in the mall sell their recyclables, which are purchased and reused by local communities. In addition, the SM City Cebu Mall has established Waste Market Day on Saturday, where barangay residents can buy or sell their recyclable materials.
- **Increased recycling through partnerships with environmental institutions**. Cebu and the Office of the Environmental Committee support women's organizations with a weekly "Cash from Trash" program. Local communities gather and transport recyclable items to a designated collection site. Here, each barangay is assigned a respective buyer for the recyclable materials.

For more information, see UNEP and the IGES' case study, ***Planning and Implementation of Integrated Solid Waste Management Strategies at the Local Level*** (IGES and UNEP 2017).

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5 PLANNING SYSTEMS

Key Resources

- Improving Solid Waste Disposal in San Cristobal Municipality, Dominican Republic (U.S. EPA 2018c)
- Decision-Maker's Guide to Solid Waste Management, Volume II (U.S. EPA 1995)
- Developing Integrated Solid Waste Management Plan, Training Manual; Volume 4: Integrated Solid Waste Management Plan (UNEP 2009c)
- Developing Integrated Solid Waste Management Plan, Training Manual; Volume 2: Assessment of Current Waste Management System and Gaps Therein (UNEP 2009b)
- Global Waste Management Outlook (UNEP 2015)

Section 5

Planning Systems

Evaluation and planning are critical steps for cities that are looking to create or evaluate a solid waste management system. Cities are best positioned to assess their own needs, evaluate current conditions, and plan for the future. This section identifies the major steps for planning and evaluating a waste system.

Why is Planning Important for Solid Waste Management Systems?

Solid waste management systems can be affected at various stages by various stakeholders, and can also be impacted by a variety of external factors. It is important to go through the planning process to acknowledge the effects that one management decision can have at each stage. Having a formal plan will assist cities in making a smoother transition to implementation and keeping solid waste projects on track. These plans can also ensure continuity of the solid waste management system in the case of staff turnover within departments responsible for solid waste management, as well as political changes. Planning is particularly important for implementing a solid waste management system because of the large number and variety of stakeholders involved. More information on best practices for stakeholder engagement is available in the *Stakeholder Engagement* section.

Key Steps in Planning

Solid waste management system planning can involve a wide range of activities. Key steps that many other cities have taken are described below. For more detailed guidance on establishing solid waste management systems, see the *United Nations Environment Programme's training manual on solid waste management planning* (UNEP 2009c).

1. **Identifying, inventorying, and assessing resources.** Cities have found it helpful to understand their own needs before creating a solid waste management system. It is also helpful to have a political commitment to solid waste management, a person or group to provide leadership throughout the process, and a plan for public involvement (Tchobanoglous and Kreith 2002). This step also involves creating an inventory of current resources and existing operations by looking at existing infrastructure, nearby facilities, and other public and private resources. Other relevant information to gather includes:

    - Information about waste type and volume (see the *Waste Characterization* section)
    - Cost assessments of equipment and labor
    - Demographic data (e.g., population, number of businesses and households, future projections).

    If data are not available for a specific area, it may be beneficial to request data from nearby communities to compare or develop an estimate for a baseline analysis. Once the data are collected, they can be organized in a way that best suits the identified objectives. One way to categorize data is by associated function in the solid waste management system (i.e., waste reduction and minimization, waste identification and characterization, waste storage and collection, composting, recycling, or disposal). Other applicable categories include administration, education and outreach, and financial resources. *The City MSW Rapid Assessment Data Collection Tool* (CCAC 2020) created by the Climate and Clean Air Coalition Municipal Solid Waste Initiative provides a template to assist cities in identifying and collecting data for solid waste management plans.

For more information, see the United States Environmental Protection Agency's ***Decision-Maker's Guide to Solid Waste Management, Volume II*** (U.S. EPA 1995).

KEY POINT

The Five *P*s for Solid Waste Management

The following five Ps are especially relevant to consider when creating a solid waste management system:

Planning: Formulating and following a well-devised and comprehensive plan.

Price: Basing a plan on a sound economic analysis.

Publicity: Using public platforms to promote a plan, gain public support, and educate residents.

Politics: Sustaining political support during the planning and implementation phases.

Perseverance: Preparing for a long-term implementation strategy.

2. **Identifying needs.** Cities can use the collected data to help assess their solid waste management needs. These needs should reflect present-day realities and also consider future changes (e.g., population growth, consumption trends, waste generation rates). It is helpful to identify data gaps for future planning and evaluation as a part of the needs identification process, but a well-established approach is to use the best-available data for planning efforts. *Volume 2 of the United Nation Environment Programme's Training Manual for Developing Integrated Solid Waste Management Plan* (UNEP 2009b) offers directions on how to assess a solid waste management system and identify gaps. Planning for disasters and other significant disruptions is a key need in many cities. Exhibit 5.1 provides a case study on disaster waste planning in Nepal.

3. **Setting goals and objectives.** Goals and objectives establish a clear vision for the development of a solid waste management system. A goal statement helps to identify the overall desired outcome of a solid waste management system. Goal statements can include the value and roles of different stakeholders, including other policymakers and residents. Objectives are measurable and monitored incremental achievements that are part of the overall goal.

4. **Evaluating solid waste management options.** Solid waste management systems incorporate a range of technology and policy options. To evaluate options, cities typically refer to the list of identified needs, goals, and objectives; and evaluate the feasibility of all possible solutions. The evaluation should also consider available technical and financial resources. Both short- and long-term solutions can be identified based on current needs and locally available resources. It is a best practice to consider each option holistically because each part of the solid waste management system affects other parts. Some examples of evaluation criteria include:

   - Regulatory requirements
   - Economic impacts
   - Applicability based on the waste stream.

5. **Defining recommended solid waste management options.** Local authorities and decision-makers can then use the evaluation to select possible solid waste management options to incorporate into the system. It can be helpful

CASE IN POINT

Sample Feasibility Studies

To save resources, cities can look for examples of past feasibility studies for solid waste management projects. The ***Global Methane Initiative*** [GMI Undated(e)] and the ***Climate and Clean Air Coalition Municipal Solid Waste Initiative*** (CCAC 2018c) are good sources of information on cities' experiences. They include links to feasibility study reports, such as the ***pre-feasibility study for an organic waste treatment project in Quito, Ecuador*** (CCAC 2018c).

to evaluate and prioritize options using the S.M.A.R.T. method, which ensures that options are specific, measurable, attainable, relevant, and timely. Options can be recommended to improve the current system, add to a specific element in the system, or develop a new project or service.

6. **Developing an implementation strategy.** Developing an implementation strategy includes identifying specific actions, responsible parties, and a timeline. The implementation strategy typically includes details on how the city will monitor progress in order to measure achievements in reaching the stated goals and objectives.

7. **Securing funding for implementing the solid waste management system.** Funding can present a significant barrier for some cities. Many cities struggle to recover costs for solid waste management services (e.g., through collection fees), and accessing external financing for capital projects can be very complicated. For more information on economic considerations of solid waste management, see the Economic Considerations section.

8. **Implementing the plan**. Once the city develops a plan and secures funding for it, and there is support from stakeholders, implementation can begin. The planned system or project can be implemented by public or private entities, or a partnership between them. For example, it is common for certain aspects of solid waste management to be implemented through a contract between the city and a private company that offers collection and disposal services. In these cases, the city may develop a Request for Proposals for parties with the ability to provide these services. Private companies can then submit proposals, and the city can evaluate the various bids and enter into a contract with the selected company. Many cities prioritize contracts with the private sector that are performance-based, with payments linked to the quality and quantity of work completed.

9. **Monitoring and evaluating the system.** It is important to continuously monitor and evaluate the solid waste management system and adapt plans and activities as needed. Monitoring and evaluation should occur on a regular, predetermined basis, as this will help the plan remain relevant to the city, identify areas for improvement, and can also help highlight successes of the program over time. Cities can design metrics or performance indicators during the planning stage that help measure the success of the program. It is important to ensure that metrics are based on data that the city is able to collect. The results of the monitoring and evaluation step can also be shared with stakeholders and the public to demonstrate the effectiveness of the program or the steps being taken to fill gaps.

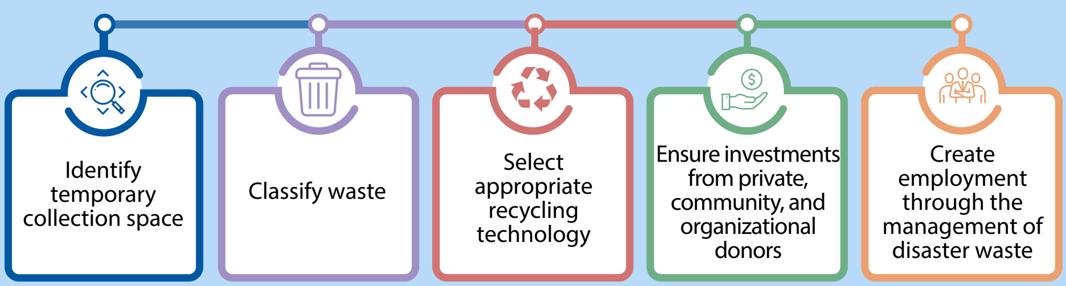
EXHIBIT 5.1 CASE STUDY

Disaster Waste Planning in Nepal

Nepal is vulnerable to natural disasters such as earthquakes, floods, landslides, and avalanches. A 2015 earthquake devastated Nepal, killing nearly 9,000 people and destroying 800,000 buildings. The earthquake generated nearly 14 million tons of waste, including both household waste and hazardous waste. Due to a lack of resources and manpower, disaster waste was not a priority for any of the local governmental bodies and in 2019, debris from the event could still be seen in Nepal.

In 2019, Leadership for Environment and Development Nepal and the United Nations Environment Programme prepared Nepal's ***"Disaster Waste Management Policy/Strategy Nepal"*** (UNEP 2018a). The plan's objectives include promoting the latest technology through public private partnerships for processing disaster waste, minimizing the production of disaster waste, and developing techniques and infrastructure to dispose of highly harmful waste. The policy outlines six main strategies for reaching these objectives:

- **Further integrate disaster waste planning into existing laws and legislation related to solid waste management such as the Disaster Risk Reduction and Management Act of 2017.** This Act places the removal of disaster-generated waste under the roles and responsibilities of district disaster management committees and states that public and private commercial establishments have a responsibility to appropriately manage waste and pollution to minimize adverse impacts to people following disasters.
- **Enhance the administrative and technical abilities of organizations that handle disaster waste management through capacity-enhancement programs.**
- **Reduce the production of disaster waste through stricter building and construction policies that improve land-use classification and building construction criteria**. The plan also suggests using local construction materials for infrastructure and spreading public awareness about disaster waste.
- **Manage disaster waste through the implementation of a unified solid waste management principle.** The steps include:



- **Secure necessary funding for disaster waste management,** including utilizing a disaster management fund for provincial and local governments to handle transportation, human resource mobilization, policy formulation, and planning related to disaster waste.
- **Evaluate how to minimize the effect of disaster waste on human and environmental health**. This process involves forming an inspection and evaluation committee at all government levels to study the effects of solid waste management and prepare proper criteria for minimizing the impacts of disaster waste and final disposal of disaster waste.

6 ECONOMIC CONSIDERATIONS

Key Resources

- Using Internal Revenue Streams and External Financing for Solid Waste Management Projects (CCAC 2018c)
- Primer for Cities for Accessing Financing for Municipal Solid Waste Projects (ISWA 2017c)
- Sustainable Financing and Policy Models for Municipal Composting (World Bank 2016)
- Explainer: How to Finance Urban Infrastructure? (C40 Cities 2017)
- Financing Readiness Questionnaire (CCAC 2018b)
- Results-Based Financing for Municipal Solid Waste (World Bank 2014)
- Municipal Solid Waste (MSW) PPPs (World Bank 2019a)
- Municipal Finances: A Handbook for Local Governments (Farvacque-Vitkovic and Kopanyi 2014)
- Global Development Alliances (USAID 2019)
- International Environmental Finance Tools (U.S. EPA 2011)
- Plastics Policy Playbook: Strategies for a Plastic-Free Ocean (Ocean Conservancy and Trash Free Seas Alliance 2019)

Section 6

Economic Considerations

The operational costs of collecting, treating, and disposing of solid waste, and communicating with stakeholders create a significant financial burden for many cities in developing countries, which can create a barrier to implementing a successful solid waste management system. In some instances, solid waste management accounts for the largest portion of the local budget; on average, solid waste management accounts for 20 percent of local budgets in low-income countries (Kaza et al. 2018). Cities often find it difficult to track and understand the full range of costs for solid waste management services, as different parts of the system are handled by various departments and partners.

Securing funds for large capital projects, which requires accessing financing from external sources, can be even more challenging. Often, even when cities are able to procure initial investments, projects can fail due to a failure to properly plan for the operational expenses of solid waste management facilities. Moreover, because every city's economic, legal, and regulatory conditions are unique, there is no simple solution to address the financial challenges associated with effective solid waste management. Fortunately, there are a number of successful strategies cities have used to more effectively recover solid waste management costs and secure financing for large projects.

This section provides an overview of common solid waste management costs and ways that cities have offset those costs by using internal funding sources (e.g., collection fees) and external financing. It also provides a well-established approach to accessing financing for solid waste management projects.

Solid Waste Management Costs

Examples of common types of costs associated with solid waste management projects for both services and facilities include:

- **Planning and administrative costs.** Cities often incur costs for conducting solid waste management studies and assessments, developing future plans and designs, and engaging with stakeholders and communicating with households. It is a best practice to incorporate these costs in budgeting for a solid waste management project.

- **Investment costs.** Investment costs vary based on how significant the project is in the context of the city's solid waste management system. Project investment costs cover everything from the planning process to initial implementation, and include feasibility studies, technical evaluations, permitting, market research, contract negotiations, construction supervision, stakeholder engagement, land acquisition, site infrastructure, supporting infrastructure, equipment, and regulatory compliance (ISWA 2017c).

- **Operational costs.** Operational costs can be difficult to predict because situational and environmental variables may change. Generally, these costs include labor, fuel, utilities, maintenance and repairs, and feedstock costs (e.g., for anaerobic digestion projects), among other items. Less-obvious costs that may be harder to estimate include overhead (e.g., office supplies, communications), outreach and awareness, taxes and insurance, legally required monitoring and reporting, emergency response (e.g., fires or equipment failure), and capacity building (ISWA 2017c).

It is important to consider the various factors that can influence the costs identified above, including population growth and increased waste generation. Local governments often plan only to the next election cycle, overlooking the long-term strategies that are needed for a solid waste project plan. Cities have found it important to encourage best practices and provide their staff with the necessary training for a successful solid waste management program.

Internal Funding

Sources of Using Internal Funding

Common sources for solid waste management include:

- **Dedicated local revenue sources.** Cities can use local taxes, tariffs, and service charges to recover the costs of waste collection, treatment, and disposal. Service charges are typically variable by waste generator type such as households, commercial institutions, and industrial facilities. Some cities have adopted lower collection charges for rural or low-income households.

  Many cities also charge fees ("tipping fees") to waste haulers when they bring waste to a facility for treatment or disposal. These fees are then used for the upkeep and improvement of the facility. Cities can also use proceeds from the sale of recyclables, compost, biogas, or electricity from biogas projects as dedicated sources of funding to offset their solid waste management costs.

- **Local and national operating budgets.** Many cities draw upon their operating budgets to cover the costs of solid waste management, and some national governments provide subsidies to local governments to help address solid waste management funding gaps (Kaza et al. 2018). However, these sources of funding are not always reliable, and in many cases general operating budget funds can be more effectively used to support activities or programs where the opportunity for self-sustaining revenue generation is minimal. For this reason, many cities prioritize using dedicated local revenue sources over drawing from the general operating budget.

Benefits of Using Internal Funding

Using internal funding offers several benefits, including:

- Helping to ensure that consistent resources are available for solid waste management programs
- Potentially generating funding surpluses that can be used to pay for future capital projects
- Reducing perceived risks for potential project investors.

In addition, using internal funding to offset costs can help reduce the risk of inefficient solid waste management practices.

Challenges to Using Internal Funding

Cities face several challenges to capturing internal funding streams for solid waste management. Many cities struggle to calculate appropriate service fees for solid waste management. Service fees paid by generators and tipping fees paid by waste haulers are uncommon in many developing countries, and it may be politically and logistically difficult to start charging for services that were previously available at no cost. Elected officials in many cities are also hesitant to enact policies that will impose waste collection service fees on their constituents. In addition, cities that have enacted such policies often struggle to effectively enforce them. Limited administrative and financial capacity to manage solid waste management fees and other revenues can also complicate cities' efforts to use internal funding to offset solid waste management costs.

CASE IN POINT

Establishing Variable Collection Fees Tied to Socioeconomic Status

Maputo, Mozambique, has established a waste collection services fee schedule that is tied to socioeconomic status. Waste collection service fees are collected through household and business electricity bills. Households and businesses that consume more electricity are charged higher fees for their waste collection services. This revenue recovery scheme is based on the assumption that electricity consumption can serve as a proxy for socioeconomic status and waste generation. Linking waste collection service fees to electricity consumption can thus help ensure that lower-income households and businesses pay less for waste collection.

For more information, see *Economic Instruments in Solid Waste Management Case Study Maputo, Mozambique* (GIZ 2012).

More information on the challenges associated with using internal revenue sources, and the potential strategies for addressing them, is available via the Climate and Clean Air Coalition's (CCAC's) *Using Internal Revenue Streams and External Financing for Solid Waste Management Projects Fact Sheet* (CCAC 2018d).

External Financing

Internal funding is often insufficient to pay for large, capital-intensive infrastructure projects, such as the construction of a new waste transfer station or sanitary landfill. In these cases, cities often need to seek external financing from private investors, financial institutions, and other partners. Exhibit 6.1 highlights several common types of financing for solid waste management projects.

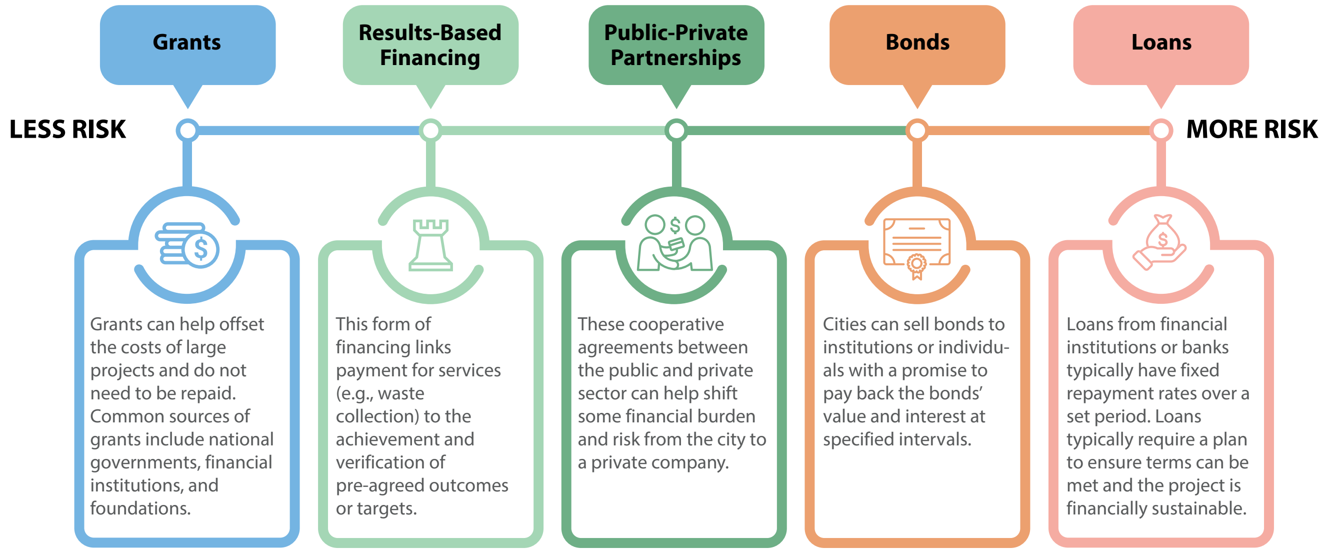
Key steps involved in securing external financing for solid waste management projects include:

1. **Carefully assessing technical needs and potential project benefits**. Before beginning to plan financial arrangements for a project, it is a best practice to carefully evaluate its technical basis. This evaluation involves conducting robust technical analyses using good data and well-established methodologies and tools. Project proposals that are based on strong technical analyses are perceived by potential investors as having lower risks. In addition, careful technical assessments can help reduce risks for cities. For example, robust technical analyses can help cities

Questions for Decision-Makers

- What are the city's true costs of solid waste management (including all operating, capital, planning, and administrative costs)?
- Are there untapped sources of internal revenue that the city can use to offset operational costs?
- What are the barriers to using those funding sources?
- What actions can the city take to address those barriers?

Exhibit 6.1. Common Types of Financing for Projects in the Waste Sector



Note: Risk refers to the risk incurred by the city in selecting a type of financing instrument for a waste sector project.

plan projects that are appropriately sized and designed; this estimate can help reduce the risk of paying for more infrastructure than is actually needed.

Careful technical analysis can also make it easier for cities to determine the feasibility of meeting their obligations under arrangements for project implementation. For example, if a city is considering engaging with a private company to build and operate an anaerobic digester that requires a consistent volume of high-quality, organic waste feedstock, the city can conduct a waste characterization study to project how much of that feedstock might be available and how it can be segregated from the general waste stream. It can also conduct a market assessment to determine the demand for the biogas and digestate produced by the project.

It is also a best practice to assess the environmental, health, and other benefits of the proposed project. For example, analyzing the air quality and groundwater protection benefits of a proposed solid waste management project can help cities secure financing from organizations that have environment-focused missions.

2. **Enhancing financing readiness**. Identifying and securing external financing for projects is a complicated and resource-intensive process. Before beginning to explore specific financing opportunities, cities have found it helpful to first consider their "financing readiness" (CCAC 2018b). Cities can enhance their readiness for financing projects by conducting a self-evaluation of the various factors that influence their ability to identify, secure, and administer financial arrangements with external partners. Cities can then work to address financial weaknesses or potential risks before trying to access financing. Key "readiness" factors include:

   - **Capacity considerations**, such as whether the city has staff and resources available for drafting requests for proposals and tenders, setting up contracts, procuring services, and managing finances.
   - **Political context**, including whether the project is at risk of being canceled by an incoming administration.
   - **Legal and regulatory factors**, such as whether there are regulations protecting potential investors and clear processes for securing approval (e.g., from the national government).

Source: Climate Bonds Initiative

CASE IN POINT

Climate Bonds for Solid Waste Management

For more information, see ***CBI's website.***

The Climate Bonds Initiative (CBI) is an organization that works to mobilize the global bond market for climate change solutions. CBI implements a variety of practices, including publishing market intelligence, providing policy advice, and establishing standards for green bonds. In 2019, they published a set of criteria for waste management bonds. By being certified by CBI, a waste management bond can prove to investors that the projects it funds meet certain mitigation and/or adaptation qualifications.

- **Funding sources**, including whether the city is efficiently recovering costs for solid waste management services.
- **Technical basis** for the project, as discussed under Step 1 above.

Additional information on questions cities have addressed as part of this readiness evaluation is available via CCAC's *Financing Readiness Questionnaire* (CCAC 2018b).

3. **Engaging with financial institutions**. Cities have found it helpful to begin working with financial institutions early in the project-scoping process. The early establishment of this relationship helps ensure that cities meet the institutions' eligibility criteria, conduct technical and financial analyses to meet the institutions' requirements, and avoid wasting limited resources. For example, many large multi-national banks do not lend to municipalities. However, by engaging with banks early in the project-scoping process, cities can understand the steps involved in working through an intermediary such as an accredited agency at the national government level.

   Cities typically work with financial institutions to identify financial instruments that are best suited for their project, and to tailor the "business case" for their proposed project. For best practices on engaging with financial institutions, see the International Solid Waste Association's *Primer for Cities for Accessing Financing for Municipal Solid Waste Projects* (ISWA 2017c).

4. **Assessing financial feasibility**. Financial feasibility assessments are a well-established approach for evaluating the economic viability and practicality of a proposed project. These assessments can require considerable resources to complete; many cities apply for technical assistance grants from foundations or other organizations to help reduce the costs of conducting the studies. Also, cities can benefit from a wide range of cost-free financial modeling tools available through international partnerships. For example, CCAC's Municipal Solid Waste Initiative offers a *financial model for assessing the economic viability of organic waste management projects* (U.S. EPA 2016c).

5. **Structuring financing and completing legal transactions**. There are many ways for cities to structure project financing. Cities have found it helpful to work closely with financial institutions and other potential partners to finalize legal transactions. The World Bank's *Municipal Finances: A Handbook for Local Governments* (Farvacque-Vitkovic and Kopanyi 2014) is a good resource for cities on structuring project financing.

For more information, see Chapter 8 in ***Improving Solid Waste Disposal in San Cristobal Municipality, Dominican Republic*** (EPA, 2018c).

KEY POINT

Types of Private Sector Arrangements

Cities typically use the following types of arrangements to secure private sector support for waste management projects:

- **Concession agreements** involve selecting a private company to provide services for a fee over a designated period of time. Concessions can involve different types of arrangements for ownership of sites and equipment. For example, a build, own, operate, and transfer concession requires that the private company build, own, and operate a facility until the end of the agreement term, at which time it transfers ownership to the city.
- **Design and construction agreements** involve selecting engineering firms to develop waste management infrastructure. These agreements would not include site operation and management.
- **Service contracts** involve selecting a company to take on the responsibility for the day-to-day operations of a facility or service. These can be performance-based contracts, with payments tied to a contractor's effectiveness.

Contracting with the Private Sector

Public-Private Partnerships (PPPs) are long-term contracts between private parties and a government entity to provide public services. In such arrangements, the private party takes on a substantial portion of the project risk and management responsibility with the prospect of generating profit over the long run (PPP Knowledge Lab 2019). Using these formalized contracts, private companies can construct, operate, and maintain waste facilities. This agreement can be an advantage when technical expertise may be limited, such as in some developing countries.

To be successful in a developing country, a PPP must be flexible, provide secure and proven products, ensure value for the money, and meet environmental performance requirements (USAID 2019a). PPPs in the solid waste sector are usually funded by collection fees, tipping fees, or other direct user charges; as such, it is critical to ensure stakeholder buy-in before entering into this type of legally binding partnership. They can also be funded by revenues from the sale of waste treatment byproducts, including biogas, electricity, and compost.

PPPs are typically structured to last over long time periods, which limits cities' flexibility. In many countries, private firms are reluctant to invest in local projects because they are uncertain whether the contract will remain valid when the administration changes. Companies typically require long-term contracts to recover their investments and make a profit.

Extended Producer Responsibility

Cities in developing countries may find their access to the sources of financing discussed above is limited or insufficient to cover all costs of solid waste management. For example, in some developing countries, instituting local taxes to cover waste management costs may not be feasible due to limited capacity for residents to pay and inadequate enforcement mechanisms.

In such cases where opportunities for using internal revenues are limited, some governments have used

CASE IN POINT

Extended Producer Responsibility in South Africa

For more information, see the ***company's website*** (PETCO 2020).

In 2004, the South Africa polyethylene terephthalate (PET) industry voluntarily created a company (PET Recycling Company NPC, or PETCO) to implement the industry's EPR efforts. Under the PETCO system, companies that convert PET resin into goods pay a levy on the amount of resin they purchase. PETCO uses the money collected through the levy to fund PET recycling initiatives, consumer education and outreach, and other activities.

extended producer responsibility (EPR) systems to reduce the public's financial burden for waste management. These systems, which are typically adopted at the national level, usually establish a legal requirement that producers assume responsibility for goods that have reached the end of their useful life. This responsibility is often financial, but can be administrative and logistical. In some instances, producers are required to pay cities directly to compensate for the cost of collecting and disposing of goods they originally produced. Producers often incorporate this cost into their product prices, thus ensuring that both producers and consumers of certain goods bear the burden of solid waste management, rather than the general public.

EPR has been used in developing countries to manage waste from a variety of product types, including packaging, household hazardous wastes, batteries, and electronics. Governments have used numerous types of EPR instruments, often combining multiple instruments into one EPR package. Common EPR programs include (Akenji 2012):

- **Product take-back requirements.** Producers are required to collect products at the end of their useful life.
- **Performance standards.** These standards can set a minimum recycled content for products, or determine the amount of post-consumer products that producers are required to recycle. These standards incentivize the use of product components that are easier to reuse or recycle.
- **Deposit-refund schemes.** Consumers are required to pay a deposit when purchasing a product, but they are later refunded the deposit when returning the product for recycling or safe disposal.
- **Advance disposal fees.** Consumers are required to pay a fee at the time of purchase that reflects the cost to manage the post-consumer waste.
- **Material taxes.** Producers are required to pay a tax on raw materials that reflects the environmental impacts of product disposal. These taxes can incentivize producers to use more environmentally friendly materials.
- **Eco-labels and awareness raising.** Public awareness campaigns can help educate consumers about more environmentally friendly products; and about the waste collection, separation, and treatment process. Informed consumers can make better product choices at the time of purchase.

Cities can face several challenges when instituting EPR systems. The most common challenge cities in developing countries face is insufficient infrastructure for collecting and treating the waste stream components covered under the EPR system. In addition, for some waste streams it can be challenging to identify the producer that should be responsible for the end-of-life collection and treatment. For example, in some Asian countries, small businesses rebuild and sell secondhand electronics, sometimes adding imitation brand logos to help resell the product (Kojima et al. 2009). This refurbishment makes it difficult to identify the original producer when the products reach their ultimate end of life.

Exhibit 6.2 presents an example of how local governments have worked with the private sector to finance solid waste management projects in the West Bank and Gaza.

EXHIBIT 6.2 CASE STUDY

Public-Private Partnership in the West Bank and Gaza

For many years, solid waste in the West Bank and Gaza was disposed of in unregulated dumpsites or burned illegally. Unstable political and economic conditions hindered municipalities from investing sufficiently in solid waste management infrastructure and services. To help mitigate this situation, The World Bank, the European Commission, the United States Agency for International Development, and the Government of Italy provided funding for a sanitary landfill at Al-Minya, two transfer stations, and related infrastructure for Hebron and Bethlehem in the Southern West Bank. This area is home to nearly 1 million people who generate almost 500 metic tonnes of waste each day.

Local governments did not have the capacity to sustainably manage this new infrastructure, so the Joint Services Council for Hebron and Bethlehem (JSC-H&B) worked with the International Finance Corporation to design a PPP to identify a private sector partner who could manage the landfill. In September 2013, JSC-H&B signed a contract with a Greek consortium, W.A.T.T. S.A.-MESOGEOS S.A. and EPEM S.A., to manage the Al-Minya landfill, two transfer stations at Hebron and Tarqoumiya, and the transfer of waste between the transfer station and the landfill. Local municipalities are still responsible for primary waste collection, and JSC-H&B provides a minimum waste guarantee of 500 metric tonnes per day and pays fees per ton of waste managed. Because JSC-H&B was not able to cover the costs of the PPP, the World Bank group also structured an $8 million output-based grant from the Global Partnership on Output Based Aid to help cover operating fees and improve the sustainability of the solid waste management system.

The project has created over 100 jobs, improved services for 840,000 residents, and will reduce greenhouse gases by 13,400 metric tonnes by 2021. Additionally, another grant by The World Bank ensured that informal sector workers were trained to work in other areas.

For more information, see ***Public-Private Partnership Stories Fact Sheet on the West Bank & Gaza*** (IFC 2013)**, and** ***Lessons from the West Bank's first PPP*** (World Bank Blog 2019).

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7 WASTE CHARACTERIZATION

Key Resources

[Developing Integrated Solid Waste Management Plan, Training Manual; Volume 1: Waste Characterization and Quantification with Projections for Future](#) (UNEP 2009a)

[Webinar: Best Practices for Waste Characterisation](#) (CCAC and U.S. EPA 2018)

Section 7

Waste Characterization

Waste composition is different in every city, urban center, country, and region worldwide. Generally, low- and middle-income countries have a higher percentage of food/organic waste in their waste streams than high-income countries; while high-income countries have a higher proportion of recyclables such as paper, cardboard, plastic, and metal (Kaza et al. 2018). These different types of waste call for different solid waste management strategies, so cities have found that an understanding of their waste streams is necessary to design and implement a relevant and applicable system.

This section provides an overview of sources of solid waste, methods of quantification, and best practices for waste characterization.

Why Is Waste Characterization Important?

Information about the sources, quantity, and composition of waste provides the foundation for all stages of a successful solid waste management program. In particular, understanding the following factors helps cities design and implement strategies to improve specific aspects of their solid waste management strategies:

- **Waste prevention and minimization.** Understanding the waste stream helps local authorities and decision-makers develop targeted outreach campaigns and policy measures. For example, outreach campaigns could encourage large-scale organic waste generators (e.g., produce markets) to build biodigesters to generate biogas and digestate as a soil amendment, an additive that improves the soil from food waste. Cities can also use data from waste characterization studies to identify non-recyclable materials that should be targeted as part of waste prevention outreach strategies or policy measures.
- **Waste collection.** Understanding the waste stream helps local authorities and decision-makers plan collection and storage facilities and programs (e.g., knowing the quantity and type of organic waste generated will influence decisions about potential source segregation programs).
- **Waste recycling and treatment.** Understanding the waste stream helps local authorities and decision-makers develop appropriate infrastructure and plan for changes in the waste stream due to seasonal changes and holidays. For example, a city would need to know the amount of organic waste generated within its boundaries to make decisions about the appropriate size of a potential compost facility that can also handle increased inflow during certain periods.
- **Waste disposal.** Understanding the waste stream helps local authorities and decision-makers plan for the disposal of waste. For example, a waste characterization study at an existing disposal site helps a city determine the baseline situation and the effectiveness of the solid waste management program, estimate the remaining lifetime of the disposal site, and plan further waste diversion and treatment options in the future.

Safety is an overarching concern throughout all stages of solid waste management. Some wastes require special handling due to corrosivity, toxicity, or other dangerous characteristics. Understanding waste composition allows workers to take adequate precautions. For more information, see the *Identification of Special Wastes* section.

Best Practices

This section describes several best practices for understanding the waste stream, including knowing the sources, quantity, and composition of waste; developing future projections of waste; and accounting for special wastes.

Assessment of the Waste Stream

A baseline assessment of current waste stream characteristics is necessary for projecting future waste generation and composition rates. It is also necessary for understanding what resources (capital and otherwise) cities might need in the near-term to properly manage different fractions of the waste stream.

Sources

Solid waste can be categorized by where it comes from. Common waste generation categories include:

- **Residential.** Includes all types of households, such as single-family homes, apartments, and other types of formal and informal housing. Waste generated by this sector usually includes food and organic waste; textiles paper and cardboard; and small portions of glass, rubber, leather, and metals. A small portion of plastic is also included; this fraction tends to increase with economic growth and globalization (UN-Habitat 2010). Household hazardous waste is a subset of residential waste that includes chemicals such as paints, solvents, cleaning agents, batteries, and electronics. These wastes are addressed in the *Identification of Special Wastes* section.
- **Commercial.** Includes office buildings, shopping malls, hotels, airports, restaurants, and markets. Markets, restaurants, canteens, and hotels tend to have waste streams with a high percentage of food waste and other organic components. Offices, hotels, and warehouses tend to generate a large quantity of recyclables such as paper, cardboard, plastic, and glass.
- **Institutional.** Includes schools, medical facilities, and prisons. Institutional facilities often generate large quantities of paper. Some institutions – including hospitals and schools – also generate high volumes of food waste. Medical facilities generate hazardous waste, which should not be handled with general solid waste. Management options are addressed in the *Identification of Special Wastes* section.
- **Industrial.** Includes manufacturing or industrial process facilities. Packaging components, lunchroom and restroom wastes, textiles, scrap metal, wood/lumber scrap, masonry/concrete, and similar wastes are typical waste products from industrial facilities. The type of waste produced is related to the type of industry, but is typically produced in high quantities. Industries usually produce both hazardous and non-hazardous waste, so it is a best practice to ensure that the hazardous waste is managed based on the country's legal requirements and is not mixed in and collected with non-hazardous solid waste (UN-Habitat 2010).

Quantity

Two basic options determine waste quantities: modeling and measurement. Many cities use modeling techniques that rely on generic waste generation rates to estimate the total amount of waste generated. These techniques are typically inexpensive, but they provide only a general idea of waste volumes and types. Using such generic data increases the likelihood of miscalculating waste generation quantities and rates (UN-Habitat 2010). As such, modeling outputs may not be a true reflection of the local waste stream. Modeling techniques work best if the waste quantity data come from a neighboring city with similar demographics and sources, and are then verified later through physical testing methods.

Physical *measurement* techniques are more accurate than modeling techniques, but are also more expensive and time-consuming. Such techniques involve sampling the local waste stream to develop a waste profile through statistical methods to predict total waste stream quantity and composition by analyzing small volumes of the waste. This audit can be challenging because samples should be tested multiple times throughout the year to account for seasonal variations (U.S. EPA 1995). A variety of measurement techniques, which could be carried out solely or combined with other techniques, include (UNEP 2009a):

CASE IN POINT

Kampala, Uganda's Waste Characterization Study

For more information, see Komakech et al.'s ***paper on the waste characterization*** **study.**

The City of Kampala, Uganda, conducted a waste characterization study in 2012 to assess the amounts and types of waste disposed of in the Kiteezi Landfill. The city randomly sampled waste from trucks entering the landfill, and further analyzed the organic waste to determine its energy content. The results of the study were very different from those of other Sub-Saharan African cities such as Abuja, Accra, and Gaborone.

- **Measuring at the point of generation.** Sampling techniques measure waste generated by conducting a survey of households. Some cities have also conducted studies at select institutional, industrial, and commercial facilities.
- **Examining records maintained by waste generators.** Some commercial, industrial, and institutional generators may have records on the amount of waste they generate. Cities could use this information to estimate quantities generated by these sectors.
- **Conducting vehicle surveys.** Surveys of waste collection vehicles provide estimates of waste generated by different sources and how they are being managed (e.g., treatment, disposal). However, this technique does not account for uncollected or improperly disposed of waste.
- **Examining records at disposal facilities.** Most disposal facilities weigh incoming waste. While these records provide an estimate of waste disposed of at a facility, they do not capture the amount generated and treated (e.g., recycling, composting) or improperly disposed of (e.g., open burning).

Composition

Many cities have used waste characterization (or composition) studies to identify the specific types and quantities of materials in the waste stream from a designated area. These studies, which typically involve sorting waste samples by hand, can be customized to meet local needs. The comprehensiveness of categories and material types (Exhibit 7.1) measured depend on the study's goals and the types of waste prevalent in a particular city. Waste characterization studies are typically conducted at the following locations:

- **Waste generation sites.** Cities often conduct characterization studies by sorting waste samples collected from residences or in commercial areas (e.g., at produce markets).
- **Transfer stations.** Waste collected from generation sites (e.g., homes and businesses) is often stored at a transfer station before being hauled to a disposal site. Samples from transfer stations could provide a profile of the city's waste composition. Sampling at multiple transfer stations could provide information to inform city-wide decision-making.

Exhibit 7.1. Sample Waste Categories and Materials for Waste Characterization (Source: U.S. EPA 2018f)

Waste Category	Material Type	Examples
Paper	Newspaper/print	Newspapers
	Compostable paper	Tissues, napkins, paper towels
	Corrugated cardboard	Packing/shipping boxes
	Office paper	Envelopes, copier paper, letterhead
	Mixed paper	Magazines, junk mail, paperboard, catalogs, phone books
	Wax-coated containers	Milk/juice cartons
Plastic	Plastic containers/bottles (#1–7 and unidentified)	Yogurt, soda, butter, prescription, milk, detergent, flower pots
	Plastic film	Shopping/garbage bags, loose film, food packaging
	Polystyrene	Expanded or regular clamshells, cutlery, cups
	Other rigid plastic	Buckets, toys, storage totes, furniture
Food waste	Bone	Bone
	Food scraps	Vegetables, meat, bread
Other solid waste	Disposable diapers	Disposable diapers
	Fine residue	Small indistinguishable materials, usually 0–2 centimeters
	Other waste	Materials that do not fit any other category
Metal	Other scrap metal	Other scrap metal, both ferrous and non-ferrous
	Ferrous containers	Pet food cans, soup cans, aerosols
	Non-ferrous containers	Soda cans, beer cans
Glass	Clear glass	All clear glass
	Colored glass	All colored glass
Yard waste	Hard plant fiber	Woody materials – brush, branches, stumps
	Garden waste	Foliage, grass, non-woody materials
Other organics	Cotton	Cotton
	Textiles	Clothes, shoes, fabric, towels, rags
	Leather	Belts, shoes, purses
	Rubber	Gloves
Electronics	Electronics	Cell phones, radios, computer
Hazardous	Hazardous	Paint, batteries, sharp medical instruments, chemicals, medical waste
Inert waste	Pallets/lumber/wood	Pallets, scrap wood
	Earthenware/ceramics	Dishes, cups
	Construction materials	Gravel, bricks, asphalt, concrete, dirt

KEY POINT

Risks Associated with Oversizing Waste Treatment Facilities

Some cities have unintentionally purchased or constructed oversized waste treatment facilities as a result of limited or low-quality data about the quantity of waste generated in their communities, which results in unnecessary, excess capital costs. For this reason, cities often err on the side of conservative facility sizing.

- **Disposal sites.** Waste that is delivered to the local landfill or dumpsite can be sampled to determine the waste composition. Recording the source (e.g., neighborhood and sector) of the waste enables a more detailed analysis of the characterization.

Waste characteristics vary by location due to recycling and improper disposal practices. The location of the waste characterization should be selected based on the desired analytical objective. For example, waste characterization efforts at waste generation sites could assist in outreach efforts to waste generators while those at disposal sites could help identify alternate treatment options, especially as disposal sites run out of capacity. Exhibit 7.2 presents an example of how one city in Mexico is using the results of a waste characterization study to plan a waste treatment project.

Development of Future Projections

Cities have found it essential to project future waste generation rates and composition in order to size and design appropriate programs and facilities to treat that waste.

Future Generation

Accurately predicting future trends in local waste generation is crucial to long-term program viability. Cities have found that the most important factors to consider are population changes, economic development, and public policy changes.

- Local and regional population trends are usually monitored and projected by national agencies
- Economic development has a direct relationship with waste generation rates; per-capita waste generation increases with an increase in economic development and a change in consumption behaviors
- Public policy shifts can quickly change the quantity and type of waste materials available to support a given option.

Future Composition

Changes in the composition of the waste stream are a considerable source of future uncertainty. While national generic estimates are difficult to apply locally, they can be a good starting point to consider when planning a solid waste management program.

Many cities have found it helpful to consider the following general trends concerning solid waste composition when conducting long-term planning for waste disposal:

- The fraction of paper, plastic (particularly packaging), and electronic wastes generally increases as economic status advances.
- The fraction of food and green waste generally decreases with the advancement of economic status (see Exhibit 7.3).
- The bulk density of waste decreases with increasing levels of economic development because of the higher percentage of paper and plastic products, along with the lower fraction of ash and food wastes (Savage et al. 1998).

EXHIBIT 7.2 CASE STUDY

Waste Characterization in Naucalpan, Mexico

Naucalpan, a suburb of Mexico City, faces several solid waste management challenges. First, the city transports large quantities of waste to other localities because they do not have their own disposal site, which consumes a significant amount of fuel and resources. In addition, Naucalpan does not have a systematic means of separating and treating organic waste, which accounts for a substantial fraction of the overall waste stream. This organic content, which could be recovered and used to benefit Naucalpan, is included in the waste that is disposed of in far-away landfills, where it decomposes and produces methane emissions.

For more information, see the Climate and Clean Air Coalition's ***webpage on analyzing the waste stream in Naucalpan*** (U.S. EPA 2018b).

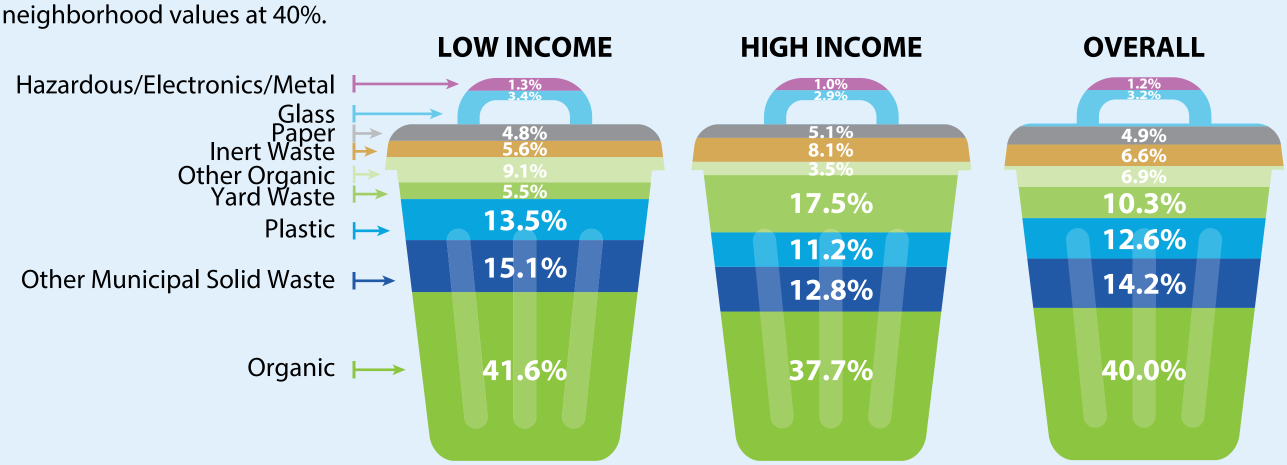
To help address these challenges, Naucalpan was considering constructing a facility to treat organic waste through anaerobic digestion. The biogas recovered from the digester will be used to generate electricity. Before undertaking this venture, however, the city needed to obtain high-quality data about their waste stream. Understanding the quantity and types of organic waste that might be used as a feedstock in the anaerobic digester was a critical first step in understanding system viability.

In 2017, the United States Environmental Protection Agency (U.S. EPA) – on behalf of the Climate and Clean Air Coalition Waste Initiative – conducted a waste characterization study at Naucalpan's transfer station. The study indicated that approximately 69 percent of the waste handled at the transfer station could be recycled or otherwise diverted from the landfill, and that more than half of the waste could be used as feedstock in composting or anaerobic digestion projects. The city is using this study's results to inform decision-making about the project's design and procurement options.

The graphic below shows the different compositions from waste streams collected from high-income neighborhoods compared to low-income neighborhoods.

Waste Composition

To determine the city's overall waste composition, the city estimated the breakdown of waste received at the transfer station and weighted the low-income neighborhood waste composition values at 60% and the high-income neighborhood values at 40%.



Identification of Special Wastes

Special wastes require dedicated handling, treatment, and disposal processes. If disposed of in the solid waste stream, these wastes can pose serious health risks to workers, surrounding neighborhoods, and the environment. However, special wastes are sometimes comingled with the municipal solid waste stream by households, commercial and industrial facilities, and other waste generators. Because of the hazards posed by these wastes, it is important to rigorously characterize waste streams, institute segregation of special wastes, and ensure separate collection and appropriate disposal of special wastes. Exhibit 7.4 identifies a number of special wastes, the hazards they present, and potential solutions for managing them.

Exhibit 7.3. Global Waste Composition by Income Level (Kaza et al. 2018).

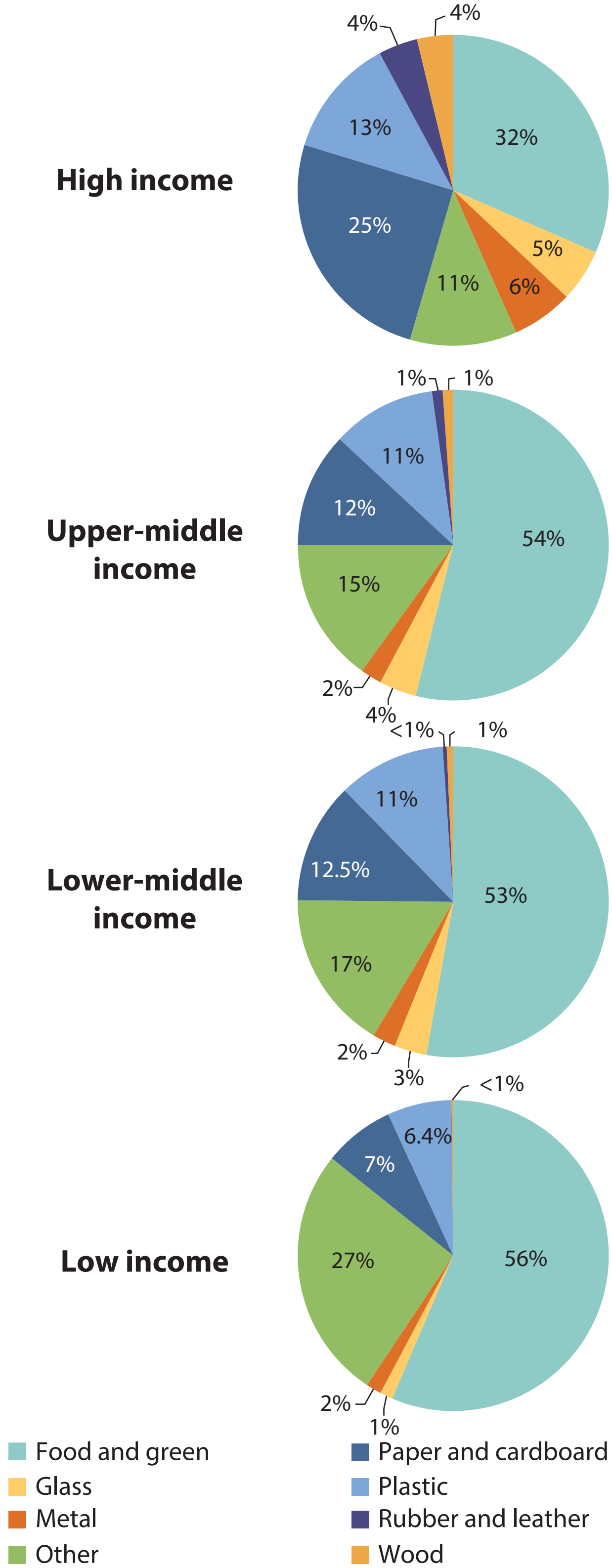


Exhibit 7.4. Special Wastes Overview and Resources

Waste	Description	Hazard	Management Solution	More Information
Electronic waste	Used electronics that are discarded or sent to a recycler	• Human exposure to contaminants and cancer-causing substances • Environmental releases	• Standards and enforcement for processing e-waste • Training and capacity building to achieve sound management practices	• United Nations Environment Programme guideline on environmentally sound material recovery (UNEP 2013)
Medical waste	Hazardous/highly hazardous medical wastes: chemicals and medicinal drugs, sharps, feces, bodily fluids, radioactive waste, and similar items	Disease transmission	• Waste segregation • Training and enforcement at medical facilities	• United States Agency for International Development Sector Environmental Guidelines: Healthcare Waste (USAID 2019c) • World Health Organization Safe Management of Wastes from Health-Care Activities (WHO 2014)
Batteries	• Rechargeable batteries used in the automotive and industrial sectors • Dry cell batteries • Lithium-ion batteries	• Environmental releases of lead particles and fumes from smelting • Human exposure: burns to skin and eyes • Environmental releases of heavy metals • Fires at waste facilities	• Improved policies and enforcement • Training and capacity-building to achieve sound management practices	• United Nations Environment Alternatives to Lead Acid Batteries website [UNEP Undated(b)] • Commission for Environmental Cooperation (CEC): Environmentally Sound Management of Spent Lead-Acid Batteries in North America (CEC 2016) • World Health Organization Recycling Used Lead-Acid Batteries: Health Considerations (WHO 2017) • Basel Convention Training Manual for the Preparation of Used Lead Acid Batteries National Management Plans [UNEP Undated(d)]
Household hazardous waste	Hazardous household products that are flammable, corrosive, or toxic (e.g., cleaners, paints, motor oil)	• Environmental releases • Flammability or chemical reactions	• Public outreach to reduce waste and improve proper handling/disposal • Programs to accept and responsibly process wastes	• U.S. EPA Household Hazardous Waste (HHW) website (U.S. EPA 2019b) • United Nations Environment Programme Solid Waste Management report *(UNEP 2005a)*
Industrial and commercial hazardous waste	Waste from commercial or industrial processes that is toxic or hazardous (e.g., solvents, ink, metal finishing waste)	• Environmental releases • Flammability or chemical reactions	• Standards and enforcement for processing hazardous waste • Training and capacity building to achieve sound management practices	• U.S. EPA Hazardous Waste Generators website (U.S. EPA 2020b) • U.S. EPA: Managing Your Hazardous Waste: A Guide for Small Business (U.S. EPA 2020c) • United Nations Environment Programme Solid Waste Management Report (UNEP 2005a)

Exhibit 7.4. Special Wastes Overview and Resources

Tires	Vehicle tires composed of complex natural and synthetic rubber compounds	• Spontaneous combustion and related releases of toxins • Environmental harm to habitats or waterways • Harboring of waterborne pathogens or disease vectors	• Outreach to automotive repair shops and vehicle scrap yards on proper storage, recycling, and disposal methods • Cooperation with recyclers to identify reuse options and markets	• *U.S. EPA Scrap Tires: Handbook on Recycling Applications and Management for the U.S. and Mexico* (U.S. EPA 2010) • *United Nations Technical Guidelines for the Environmentally Sound Management of Used and Waste Pneumatic Tyres* (UNEP 2011) • *Scrap Tire Recycling in Canada* (Pehlken and Essadiqi 2005)
Animal manure	Waste from animal processing facilities serving urban areas	• Gases and odors harmful to human health • Land or water contamination (e.g., bacteria harmful to humans, plants, or organisms)	Processes for treating (e.g., composting) or landfilling waste	• *Sustainable Animal Manure Management Strategies and Practices* (Malomo et al. 2013) • *Animal Manures: Recycling and Management Technologies* (Gómez-Brandón et al. 2013) • *Guidelines for Sustainable Manure Management in Asian Livestock Production Systems* (IAEA 2008) • *CCAC Manure Knowledge Kiosk website* [CCAC Undated(d)]
Construction and demolition waste	Drywall, roofing shingles, lumber, bricks, concrete, and siding	• Sharp objects (e.g., nails, glass) that can transmit disease (e.g., tetanus) • Mold from materials that have been exposed to the elements • Hazardous or cancer-causing materials (e.g., asbestos)	• Outreach to builders and developers on proper storage, recycling, and disposal methods • Procedures for proper landfilling	*U.S. EPA Sustainable Materials Management Options for Construction and Demolition Debris* (U.S. EPA 2018e)
Fluorescent bulbs	Burned-out light bulbs	Mercury exposure	• Processes for collecting bulbs and recovering materials (e.g., glass and mercury-containing powder) • Training and capacity-building to achieve sound management practices	*Practical Sourcebook on Mercury Waste Storage and Disposal* (UNEP 2015)

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8 PREVENTION AND MINIMIZATION

Key Resources

- Managing and Transforming Waste Streams: A Tool for Communities (U.S. EPA 2017c)
- Toolkit: Reducing the Food Wastage Footprint (FAO 2013)
- Food Waste as a Global Issue – From the Perspective of Municipal Solid Waste Management (ISWA 2013a)
- Food Waste: A Global Commitment to Halving Food Waste by 2025 (CGF 2020)
- Food Loss Analysis Reports and Fact Sheets (FAO 2020)

Section 8

Prevention and Minimization

The prevention and minimization of waste, and the processes and practices intended to reduce the amount of waste produced, is a best practice for solid waste management systems. Reducing waste and reusing materials are not only environmentally beneficial, but can deliver public health benefits and save money.

This section provides an overview of waste prevention and minimization, and how to incorporate them into a solid waste management plan.

What is Waste Prevention and Minimization?

Waste prevention, often called source reduction, means reducing total waste generation. Food waste, packaging material, and disposable products are some of the typical items in waste streams that can be targeted for waste prevention and minimization.

- **Food waste** can be addressed by redistributing food that would otherwise be wasted. Examples include the use of applications to link food donors such as restaurants, food caterers, and grocery stores to food banks; the use of community refrigerators where excess food from one household can be accessed by needier households; and awareness campaigns that can increase the consumption of produce that would otherwise be wasted because it does not have the ideal shape, size, or color. See Exhibit 8.1 for a case study on food waste reduction in Hong Kong.
- **Packaging material** in the waste stream can be minimized by seeking products with minimal packaging, and instituting fees for plastic and paper bags.

- **Disposable product** use could be minimized by encouraging the purchase of durable, long-lasting goods.

Waste prevention can be as simple as switching from disposable to reusable products, or as complex as redesigning a product to use fewer raw materials or last longer.

Why is Waste Prevention and Minimization Important?

Because waste prevention avoids waste generation, it is the most cost-effective and preferred solid waste management activity. Preventing or minimizing waste conserves resources (e.g., by reducing collection and transportation costs), protects the environment, and prevents the release of greenhouse gases (U.S. EPA 2017f).

KEY POINT

Challenges in Implementing Waste Prevention and Minimization Policies

Cities face many challenges with implementing policies that require widespread changes in consumer and commercial behavior. A number of countries have enacted policies banning or restricting single-use plastic bags. Uncollected bags frequently become litter that clogs stormwater drains, impedes wastewater treatment processes, and travels downstream to become marine litter.

Challenges countries sometimes face when banning the sale or use of these bags include:

- Vendors using plastic bags purchased through the black market
- Consumers relying on alternative bags that have other environmental impacts (e.g., bags made of unsustainable materials)
- Limited access for consumers and vendors to economically viable alternatives.

These challenges highlight the importance of working closely with stakeholders to develop robust solutions that can be enforced effectively.

Incorporating Prevention and Minimization into Solid Waste Management

Stakeholders at all levels play an important part in waste prevention and minimization, and prevention and minimization strategies should account for local social norms and practices, and economic and market conditions. The *Stakeholder Engagement* section identifies best practices for working with a wide range of individuals and organizations to design effective solid waste management strategies.

Many countries already practice some form of waste reduction because people value materials differently based on their culture. Repair and reuse, upcycle, resale, bartering, and giving used goods as gifts are practices that are encouraged in some parts of the world (UNEP 2005a).

Reducing the quantity of waste for transport and disposal is a best practice for solid waste management programs. Waste can be recovered at the source, during transport, or at the disposal site. Earlier separation is preferable because it leads to cleaner and higher-quality materials, and can also reduce transport and disposal costs. Incentives that integrate and foster the involvement of the informal sector can be essential to minimizing waste (USAID 2018). See the *Separation, Collection, and Transportation* section.

As discussed in the *Waste Characterization* section, economic development typically leads to increased consumption of different types of goods (especially electronic goods). Many cities have therefore found it helpful to account for economic development projections when planning waste prevention and minimization strategies.

EXHIBIT 8.1 CASE STUDY

Food Waste Prevention in Hong Kong

Approximately 3,600 metric tonnes of food are wasted daily in Hong Kong. Food waste represents approximately 40 percent of all solid waste that is collected and transported to be landfilled, which results in excess use of fuel, landfill capacity, and labor. Much of this food waste comes from supermarkets, which typically discard produce that do not meet consumer preferences.

PARKnSHOP, which operates nearly 300 supermarkets in Hong Kong, has been working to reduce food waste while also addressing another social concern: providing food for underprivileged populations. The supermarket chain created a partnership with a local nongovernmental organization (NGO), "Food Rescue for the Needy." Through this program, the supermarket delivers surplus food to the NGO that would otherwise be wasted, and the NGO distributes it to individuals or families in need. From 2012 to 2018, PARKnSHOP donated more than 800 metric tonnes of food that would otherwise have been landfilled.

For more information, see the PARKnSHOP profile in the ***Consumer Goods Forum's Food Waste booklet*** (CGF 2018).

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9 SEPARATION, COLLECTION, AND TRANSPORTATION

Key Resources

- Collection of Municipal Solid Waste in Developing Countries (UN-Habitat 2010)
- Best Management Practices for Optimizing Waste Collection Routes (U.S. EPA 2015)
- Waste Transfer Stations: A Manual for Decision-Making (U.S. EPA 2002b)
- Waste Collection: A Report (Kogler 2007)

Section 9

Separation, Collection, and Transportation

Effective waste separation and collection programs are a critical component of an integrated solid waste management system. These activities involve a range of stakeholders, from individual households to collection fleet operators; many cities have found it important to establish clear methods of communications and coordination among those groups. Effective waste separation, collection, and transportation also involve a variety of types of infrastructure, including receptacles for separating and storing waste before it is collected; and vehicles such as carts, bicycles or tricycles, and trucks.

This section provides an overview of the benefits and challenges of proper waste separation, collection, and transportation, as well as best practices for implementing these programs.

Why is Collection Important?

Uncollected waste results in littering, illegal dumping, and burning, which in turn can cause serious health and environmental impacts. These include:

- **Marine litter.** Plastics that travel through sewage and stormwater systems end up in waterbodies that feed into oceans. For more information on the relationship between solid waste management and marine litter, see the *Marine Litter* section.
- **Local flooding.** Waste can clog drains and slow or stop the flow of stormwater out of a city.
- **Loss of real estate value.** Unsightly waste dumped on roads or open lots can lead to lowered land values.
- **Spread of diseases.** Vermin, such as parasites, rodents, and pigs, are attracted by uncollected waste and can carry various diseases.
- **Local water pollution.** Leachate from waste dumped in open spaces can pollute local water sources.
- **Local air pollution.** Burning of uncollected waste contributes to increased local concentrations of harmful pollutants such as fine particulate matter and volatile organic compounds.

CASE IN POINT

Drain Blockage

The blockage of drains by uncollected waste was the cause of a major flood and outbreak of waterborne disease in Surat, India, in 1994 (Wilson et al. 2013). Drains clogged by plastic bag waste have also been blamed for flooding in Ghana (Hinshaw 2015) and Bangladesh (BBC News 2002). Waste may also be pushed by stormwater or blown by wind into drains from nearby collection or transfer facilities. This problem is easily preventable, and it is a best practice to place such facilities away from open drains.

KEY POINT

Collection Coverage versus Collection Efficiency

When setting collection goals, cities have found it important to distinguish between collection coverage and collection efficiency. Collection coverage typically refers to the fraction of the city's geographic area over which collection services are provided. Collection efficiency typically refers to the fraction of waste generated in a given area that is collected. A city that collects much of the waste generated in a small part of its geographic domain would thus be said to have a high-collection efficiency but low-collection coverage.

- **Global climate change.** Decomposition of organic waste in anaerobic conditions leads to emissions of methane, a powerful greenhouse gas. In addition, burning of uncollected waste contributes to emissions of black carbon, a component of fine particulate matter. Black carbon is a short-lived climate pollutant that has significant impacts on global climate change.

Challenges

Many cities struggle to increase their waste collection coverage and efficiency due to a wide range of complicating factors, including:

- **Increased volume of waste**. Rapid urbanization, population growth, and changing consumption patterns with economic growth contribute to an increase in the amount of waste generated.
- **Limited space for storing and transferring waste**. Increased population density decreases the amount of space available for community bins and transfer stations.
- **Physical obstacles to collection**. For example, cities built in valleys or on steep slopes tend to have narrow roads that are difficult to navigate for proper waste collection.
- **Shortage of funding**. Many cities face a shortage of funds, as well as competing demands to provide numerous public services.
- **Limited stakeholder awareness and participation.** Effective collection schemes depend on the public being well-informed and willing to participate, especially in instances where cities are implementing source-separated collection systems (discussed below). For more information on strategies for working with the public to raise awareness and increase participation, see the *Stakeholder Engagement* section.

Best Practices

This section describes best practices for storing and collecting waste, including understanding waste composition, identifying appropriate waste storage before collection, planning collection locations, segregating waste to facilitate collection for appropriate treatment and disposal, incorporating the informal sector in waste collection, incorporating transfer stations, optimizing collection frequency and routes, and using the most appropriate collection vehicles.

Waste Composition

Characterizing the sources, quantities, and types of waste can help a city plan for the collection of waste. For example, cities need to know the volume of each fraction of the waste stream in each part of the city in order to set appropriate collection frequencies. For more information on understanding the waste stream, see the *Waste Characterization* section.

CASE IN POINT

Door-to-Door Collection in Trichy, India

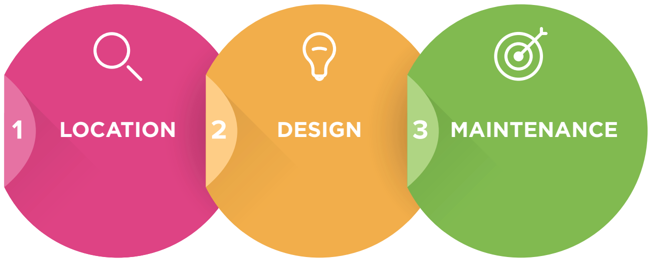
For more information, see the Times of India article, ***QR Code to Track Trichy's Waste Collection*** (Karthik 2018).

The City of Trichy piloted the use of Quick Response (QR) codes™ by providing them to residents and commercial establishments in one ward. Information is entered online instantly as waste collectors scan the QR code™ at each collection point, which ensures that no collection points are missed. Bangalore conducted a similar pilot, but expanded it to ensure proper segregation by having waste collectors upload photographs of non-segregated waste along with the appropriate QR code™.

Storage Infrastructure

Cities utilize waste storage infrastructure to aggregate collected waste before it is transported to a disposal facility. Cities use a variety of decentralized facilities and equipment to store waste, including depots; closed enclosures or pads; fixed bins or drums for communal storage; and portable bins, buckets, or bags for residential storage (UNEP 2005a).

Exhibit 9.1. Storage Infrastructure Characteristics



Cities have benefited from considering a range of factors when planning this infrastructure, including what type of container should be used for different waste types, what size container should be used, and where the containers should be located. Systems for storing waste are most effective when they are designed to account for cultural norms and practices. For example, cities can locate containers in places that are easily accessed by collection trucks in the morning when most households typically dispose of their waste. Cities can collect input from stakeholders during the storage infrastructure planning process (see the *Stakeholder Engagement* section for more information).

Location

A successful approach is to locate containers in areas that are easily accessible by collection vehicles, within walking distances of intended users, and in locations acceptable to residents. A well-designed storage system will not be effective if containers are in locations that are inconvenient for residents or waste collectors.

Design

It is a best practice to design waste collection containers so they are easy to use. Street containers that are difficult to use (e.g., if they have heavy mechanical lids) encourage people to drop their waste beside the container rather than in it. Not only does this factor result in sanitation issues, but scattered waste takes more time to load into collection vehicles. In areas where children commonly dispose of household waste, cities have found it helpful to design containers to facilitate use by children (e.g., containers that are shorter in height and have easy-to-open lids).

CASE IN POINT

Communal Collection in Addis Ababa, Ethiopia

For more information, see the city's ***waste collection activities on the Municipal Solid Waste Knowledge Platform*** (CCAC 2015).

Addis Ababa's Cleansing Authority is responsible for primary waste collection. The authority employs registered micro- and small-scale enterprises. These enterprises equip workers with 1.5-cubic-meter pushcarts to collect waste approximately daily from multifamily, residential developments, following the communal collection model. When workers arrive at a development, they alert residents (e.g., by ringing a bell) to bring their waste to the building entrance. The workers then transport the waste using pushcarts to a "skip point" (i.e., transfer station; see Exhibit 9.6), where it is stored in 8-cubic-meter containers until collected by a truck.

If waste is segregated before collection, the design of bins in residences and communal locations can encourage people to place waste into the appropriate bin. For example, bins can be color-coded for ease of waste separation; blue can represent recyclables and brown can represent organic waste. Pictures and lists of what can and cannot be placed into communal bins can be posted on or near the bins.

It is also a best practice to appropriately size the containers. If the containers are too small, waste will accumulate on the ground around them. If they are too large, individuals might be inclined to dispose of large, bulky items in the containers.

Maintenance

Maintaining areas around waste collection containers is a best practice because residents are more likely to dispose of waste outside of the containers if they are dirty or obstructed (UN-Habitat 2010). In many countries the informal sector customarily sorts through waste in communal containers, looking for items they can sell to recyclers, which can result in waste scattered around the containers. Stray animals often forage for food around waste storage containers. One approach to controlling this problem is to give informal sector workers specific responsibility for certain containers, allowing them access to the waste in exchange for keeping the area clean (UN-Habitat 2010). For more information on engaging the informal sector in solid waste management, see the *Informal Sector Recycling* section. Some cities have reduced their maintenance costs and minimized scavenging by installing containers that have above-ground receptacles and below-ground repositories that are only accessible to authorized collectors.

Collection Models

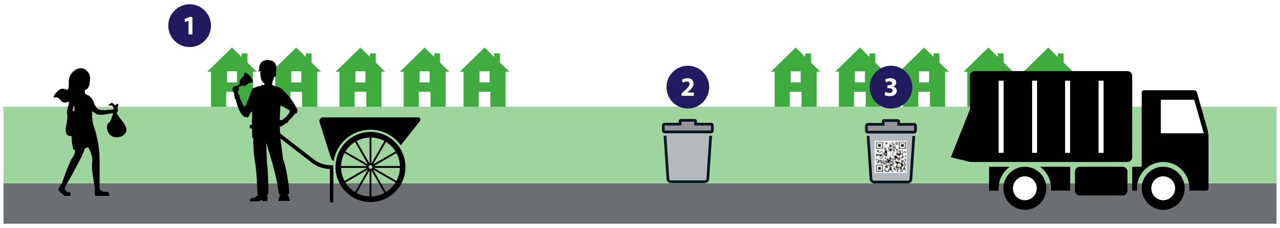
Cities use a variety of collection models to ensure high-collection coverage and efficiency. Selecting the most-appropriate collection model also helps cities avoid excessive costs. Cities typically consider a range of variables when determining which collection models are most suitable for their situation (see Exhibit 9.2).

Waste Separation

Waste separation, or segregation, before or during collection increases efficiency and reduces costs because it minimizes the labor and infrastructure costs required to segregate mixed waste. Waste can be segregated by different parties at each step in the collection process:

Exhibit 9.2. Illustrative Comparison of Collection Models

Curbside/Door-to-Door Collection



1. In curbside collection, waste is collected at each household property. As collection vehicles pass, waste collectors ring a bell or otherwise announce their arrival to alert residents to bring their waste to the street, where it is collected for transportation to a transfer or aggregation facility. Households can have a single bin, or multiple bins if source segregation is in place; see the *Waste Separation* section. With this type of collection, the city generally informs residents about the day and time of waste pickup.
2. Some cities have collection systems where bins can be left outside for hours; in these cases, a well-established approach is to ensure that the bins have lids and/or are heavy enough to prevent animals from entering them or knocking them over.
3. Technology can improve the efficiency of door-to-door collection; for example, cities can have waste collectors use Quick Response (QR) codes™ to ensure that the waste is collected and segregated properly.

Advantages:

More convenient for residents

Consistency in waste collection

Disadvantages:

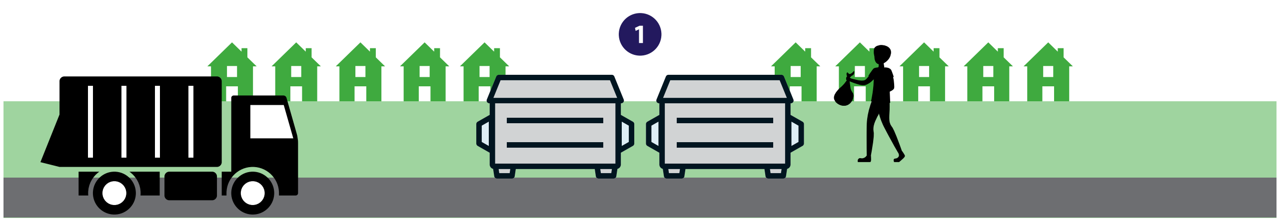
Can be costlier due to frequent vehicle stops

Some households may be inaccessible due to road conditions and vehicle size

Potential illegal dumping or burning due to infrequent collection

Missed collection if residents are not at home

Communal Collection



1. In communal collection models, residents bring their waste to large bins that are centrally located in their neighborhoods. With this type of collection, the city sends collection vehicles to remove the waste regularly. Communal collection works well when there is considerable support for participation in a dense area. Smart technology can be incorporated by having electronic monitors signal when large bins are full, which will help the city avoid overly full bins and reduce collection costs by reducing the number of trips to bins that are not full.

Advantages:

Fewer stops for collection vehicles

Less waste stored in residents' homes

Disadvantages:

Potential illegal dumping if bins are inconveniently located

Animals can enter or knock bins over if they are not designed properly

Illegal burning of waste if it is not picked up frequently

Illegal dumping of bulk waste

- **Waste generators**. Some cities provide color-coded bins to residents and ask that the waste be segregated at the source (Exhibit 9.3). For example, the Municipal Solid Waste Management Rules of India prescribe national requirements for local solid waste management. These rules dictate that green bins be used for organic waste, white bins for recyclables, and black bins for all other waste. Commercial establishments sometimes have multiple bins to separate paper, plastic, metal, glass, and organic waste.

- **Waste collectors**. In some cities, waste collectors hang multiple bags on their push carts, bicycle carts, or vehicles; and use them to segregate the waste as they collect it from households (Exhibit 9.3). They typically separate out recyclables into the bags and deposit non-recyclables, including organic waste, into a bin. If the city has an organic waste treatment facility (composting or anaerobic digester), the collector can also separate the organic waste at collection time.

- **Dedicated communal bins**. Some cities provide communal bins in multifamily housing complexes or in neighborhoods for individual residents to dispose of their waste. Many cities have segregation with color-coded bins (e.g., blue for paper and paper products, brown for organic waste, white for clear glass, green for colored glass, yellow/orange for recyclable packaging material, and grey/black for other waste).

The categories of waste that cities choose to segregate will depend on their ability to separately handle each category. It is especially important for cities to identify local and regional markets for recyclables, and tailor segregation plans accordingly. In instances where markets for certain products do not currently exist, cities can work with the private sector to spur market demand.

The informal waste sector plays a significant role in solid waste management in many developing countries. Informal sector workers segregate waste to collect recyclables from households and communal bins (Exhibit 9.5). Cities in many developing countries are working to incorporate them into formal solid

Exhibit 9.3. Waste Collection Bins in Accra, Ghana

Exhibit 9.4. Push-Cart with Waste Segregation in Coimbatore, India

Exhibit 9.5. Waste Collectors Separating Recyclables from the Waste Stream in Mexico City

Exhibit 9.6. Small-Scale Transfer Station in Addis Ababa, Ethiopia (left); and Larger-Scale Transfer Station in Coimbatore, India (right)

waste management activities. The *Informal Sector Recycling* section provides additional information on informal sector recycling.

Transfer Facilities

In many countries, large disposal sites are located far from densely populated areas. In such instances, a transfer station is used as an intermediate point where collected waste is aggregated (and sorted, if applicable) before being transferred to the disposal site. The waste is sometimes compacted at transfer stations to reduce the number of trips to disposal sites.

Benefits of Transfer Facilities

Consolidating loads from smaller collection vehicles, including bicycles and carts, into larger transfer vehicles helps reduce hauling costs by enabling collection crews to spend less time traveling to and from distant disposal sites, and more time collecting waste. This strategy also reduces fuel consumption and emissions, collection vehicle maintenance costs, road wear, and overall traffic.

Transfer stations can also serve as a location to sort and recover waste (U.S. EPA 2002b). Performing sorting and recovery activities at transfer stations contribute to fuel savings, reduced wear on trucks, and fewer trips to landfills (USAID 2018).

Different Types of Transfer Facilities

Transfer stations can include small, highly decentralized and un-mechanized facilities such as empty lots that serve as temporary disposal lots, where residents and commercial establishments may dispose of their waste or where primary collectors (e.g., collectors using handcarts and bicycles) deposit waste they have collected (Exhibit 9.5). Larger, more robust transfer stations can be used as a place to aggregate, sort, and load larger quantities of waste. Waste that arrives at these transfer stations may come directly from residents and businesses, from secondary collectors that retrieve waste from smaller transfer stations, or from city trucks that collect the waste directly from the source.

Siting Transfer Facilities

Transfer facilities should be located away from open drains to prevent waste from clogging drainage systems and entering waterways, and should be constructed or sited on impermeable surfaces. Other site selection considerations include distances that smaller vehicles need to travel from the primary collection site to the transfer station, and larger vehicles need to travel from the transfer station to the disposal site.

Collection Frequency

Cities typically collect waste at different intervals depending on a range of factors. Key considerations when specifying how frequently waste will be collected include:

- **Cost**. The greater the frequency of service (e.g., daily, weekly), the more costly the collection system will be to operate.

- **Customer expectations and timing**. Many cities have found it helpful to coordinate the timing of waste collection in commercial areas according to local business operations (e.g., collection can occur after markets close). Many cities also arrange for collection during times with less road traffic.

- **Capacity limitations**. Waste collection fleets may need to collect waste more frequently in neighborhoods where communal or household bins quickly reach capacity.

- **Climate**. Cities in tropical climates tend to collect waste daily because biodegradable waste decomposes more quickly in these climates, and begins to smell and attract flies and other disease-carrying vermin. Cities in temperate climate zones may collect waste biweekly or weekly.

Optimized Collection Routes

Optimizing waste collection routes leads to reduced labor, fuel, and vehicle maintenance costs. In addition, reduced travel time leads to lower vehicle emissions, and public health and environmental benefits. Route optimization is a four-step process (Shuster 1974):

1. Reviewing existing policies to understand the roles and responsibilities of the department that is responsible for solid waste management. This evaluation includes understanding the financing of waste collection, the labor laws affecting the waste collectors, and the service area.

2. Macro-routing the service area(s) or determining how daily collection routes are assigned, based on reviewing existing processing and disposal sites. This calculation involves determining the optimum amount of waste that can be processed and disposed of each day, and dividing the collection area into subsections or districts that collection crews can adequately service on a given day.

3. Performing route balancing and districting to ensure that the workload is distributed equally among collection crews.

4. Micro-routing the service area(s), or looking in detail at a service area to determine collection vehicle routes. This review is important for optimizing waste collection routes, potentially resulting in significant cost savings. Micro-routing takes many factors into account, including geographic features, demographic considerations, vehicle design, point-of-collection features, requirements for residents and businesses to set out their waste on the street, and collection frequency. Cities have found it important to consider route adjustments based on seasonal changes or population growth.

Some cities (e.g., East Delhi Municipal Corporation in India) have incorporated smart systems with global-positioning system locators attached to collection vehicles, which allow them to track their vehicles and ensure that the vehicles are not idling or skipping collection areas.

Collection Vehicles

The selection of waste collection vehicles can greatly impact the efficiency of a solid waste collection program. Cities typically consider the following factors in selecting appropriate vehicles:

- **Vehicle size**. It is a best practice to base vehicle size on the amount of waste to be collected. Large compactor trucks are suitable only if relatively large volumes of waste are picked up at each stop. Large trucks are not suited to frequent collections of small amounts of waste where a small truck or motorized tricycle would be more cost-effective. Large trucks are also not feasible in narrow alleys or limited roadway spaces.

- **Types of waste collected**. Segregated waste collection might require vehicles with multiple compartments, depending on the degree of segregation.

- **Frequency of stops**. The frequency of stops typically guides cities' selection to allow for vehicles' constant starting and stopping, and moving at low speeds in typical weather conditions (hot, humid, dusty) or on unpaved roads.

- **Vehicle load-carrying capacities**. Cities can estimate how many households their vehicles can serve before reaching capacity, and set a target for each vehicle to serve slightly less than that number.

CASE IN POINT

Electric Collection Vehicles in Rio de Janeiro, Brazil

Rio de Janeiro has adopted ambitious climate and air-quality goals to reduce its contribution to climate change and local air pollution. The municipal waste management corporation recently purchased a number of electric collection vehicles to collect hospital waste from several areas of the city.

For more information, see the ***Rio de Janeiro case study on electric collection vehicles*** (C40 Cities 2018).

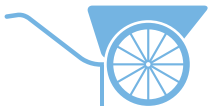
- **Vehicle maintenance**. Many cities have found that selecting vehicles that are commonly available or easy to maintain (USAID 2018) increases the reliability of a vehicle. Repairs can be made more quickly if parts can be easily purchased from local retailers without requiring foreign exchange and importation. Monitoring the condition of each vehicle via routine checks allows operators to replace components before they fail.
- **Vehicle emissions**. Cities are increasingly concerned about the contributions of heavy-duty vehicles to local air pollution. Waste collection fleets can contribute substantial amounts of particular matter to the local environment, especially because they typically operate on a daily basis, drive long distances to disposal sites, may not be well-maintained, and spend much of their time idling in traffic or at collection points. For these reasons, many cities are considering alternative fuel or low-emissions vehicles for their collection fleets.

Questions for Decision-Makers

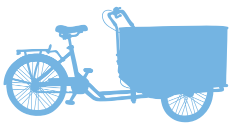
- Do the crews have assigned route boundaries?
- Have the crews' maps been updated in the past two years?
- Were the current routes developed based on time, distances, vehicle capacity, and geography?
- Has waste generation remained approximately constant since the last update of the waste collection routes?
- Are all of the crews completing their routes as scheduled?
- Does the collection services supervisor know how many stops and containers are included in each individual route?
- Does the collection services supervisor know how long each route should take?
- Are there mechanisms for users to file complaints about late or improper collection, and for reviewing and addressing those issues?

Vehicle Options

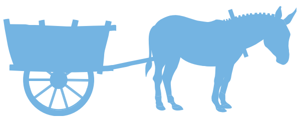
There is a broad spectrum of waste collection vehicle types, ranging from un-mechanized handcarts to large compactor trucks:



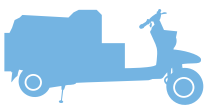
Handcarts. Handcarts can be used for door-to-door collection on narrow streets where a wide truck cannot enter. Waste is picked up by the cart and brought to a truck waiting at the end of the street. The use of handcarts increases the amount of labor needed, but ensures that all residents have access to solid waste management services. Handcarts typically have open boxes attached and are designed so that the collected waste can be picked up or emptied directly into the waste collection truck.



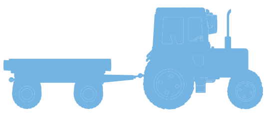
Pedal bicycles or tricycles. Pedal cycles have increased speed and the ability to reach more residents in less time. These cycles often have an attachment in the front or rear where waste is stored (UNEP 2005a).



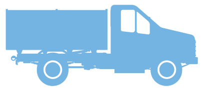
Animal carts. Horses, mules, and donkeys can also be used to transport waste on carts. The use of animal carts can be beneficial as they do not require fossil fuels, have very low capital and operational costs compared with motor vehicles, and make less noise than large collection trucks. The carts are designed to be tipped into a transfer or storage location (UNEP 2005a).



Motorized tricycles. A three-wheeled motorcycle is another way to collect waste from residents along narrow roads in urban areas. Their design is similar to that of pedal cycles and they are commonly used in Asia. Motorized tricycles use less fossil fuel than trucks, and are able to carry more weight and move at greater speeds than hand carts or pedal cycles.



Tractor and trailer systems. A tractor-trailer system allows for greater amounts of waste to be carried and then easily removed by detaching the trailer. This capability makes a tractor-trailer option a suitable option, especially for communal collection bins.



Trucks. Commercial trucks can also collect waste, especially from communal bins. The design usually includes a large flatbed walled on all sides and open at the top with a hinge tailback. These trucks are not usually designed for waste collection, and therefore require a ladder or someone to manually throw in and remove the waste.

Fore and aft tipper. This design allows for easy rear-loading while carrying high volumes of dense waste. The back of the truck can tip back and forth to compact the waste or dump its contents when at the disposal facility. These trucks are often suited for waste streams in countries that have a high percentage of dense, moist content.

Cities have found that preventing litter during the waste collection process is also important. Small amounts of waste may get scattered in the road during the waste loading process. Coordinating the work of collection crews and street sweepers can ensure that any waste dropped in this way is quickly removed. Furthermore, waste in open collection vehicles can be covered by a net or other material to prevent it from escaping.

Cost Recovery

Waste collection can account for a substantial portion of a city's operating budget. As such, cities in lower-income countries generally have less-comprehensive waste collection services than higher-income countries (Kaza et al. 2018). Establishing a means of recovering waste collection costs is a key component of a sustainable and effective waste collection program.

For more information on financing solid waste management programs, see the *Economic Considerations* section.

Marine Litter

Waste generated on land can reach marine waterbodies through various processes if it is not properly collected. For example, waste that is not collected can be dumped or blown into coastal or inland waterways (NOAA 2019). The infographic on the following page illustrates how different sources contribute to the global challenge of plastic marine litter. As the graphic shows, the majority of plastic marine litter (as much as 80 percent according to some estimates) comes from land-based sources (Eunomia Undated).

Awareness of the prevalence of marine litter at a global scale – and concern over its impacts – is rapidly growing. Simultaneously, the marine litter challenge is becoming more acute as increasing quantities of waste that degrade slowly are accumulating in the ocean. There is an international focus on improving waste collection and management options to reduce marine litter. This section identifies the impacts marine litter causes, and best practices for reducing it.

Impacts

Key impacts associated with marine litter include:

Species impacts. Fish, mammals, and plants can be directly impacted by marine litter, whether through ingestion of materials, physical damage from floating or sunken objects, or entrapment (e.g., in detached nets).

Habitat damages. Marine litter can harm entire habitats or ecosystems through physical impacts (e.g., on coral reefs) or through cascading effects on species at the bottom of the food chain.

Economic impacts. Marine litter can damage marine infrastructure and vessels, degrade aesthetics in areas dependent on tourism (e.g., beaches), and harm individuals and businesses that depend on the health of marine resources.

Best Practices

The most effective means of minimizing impacts of land-based marine litter is to focus on its sources, which involves:

Minimizing and preventing waste

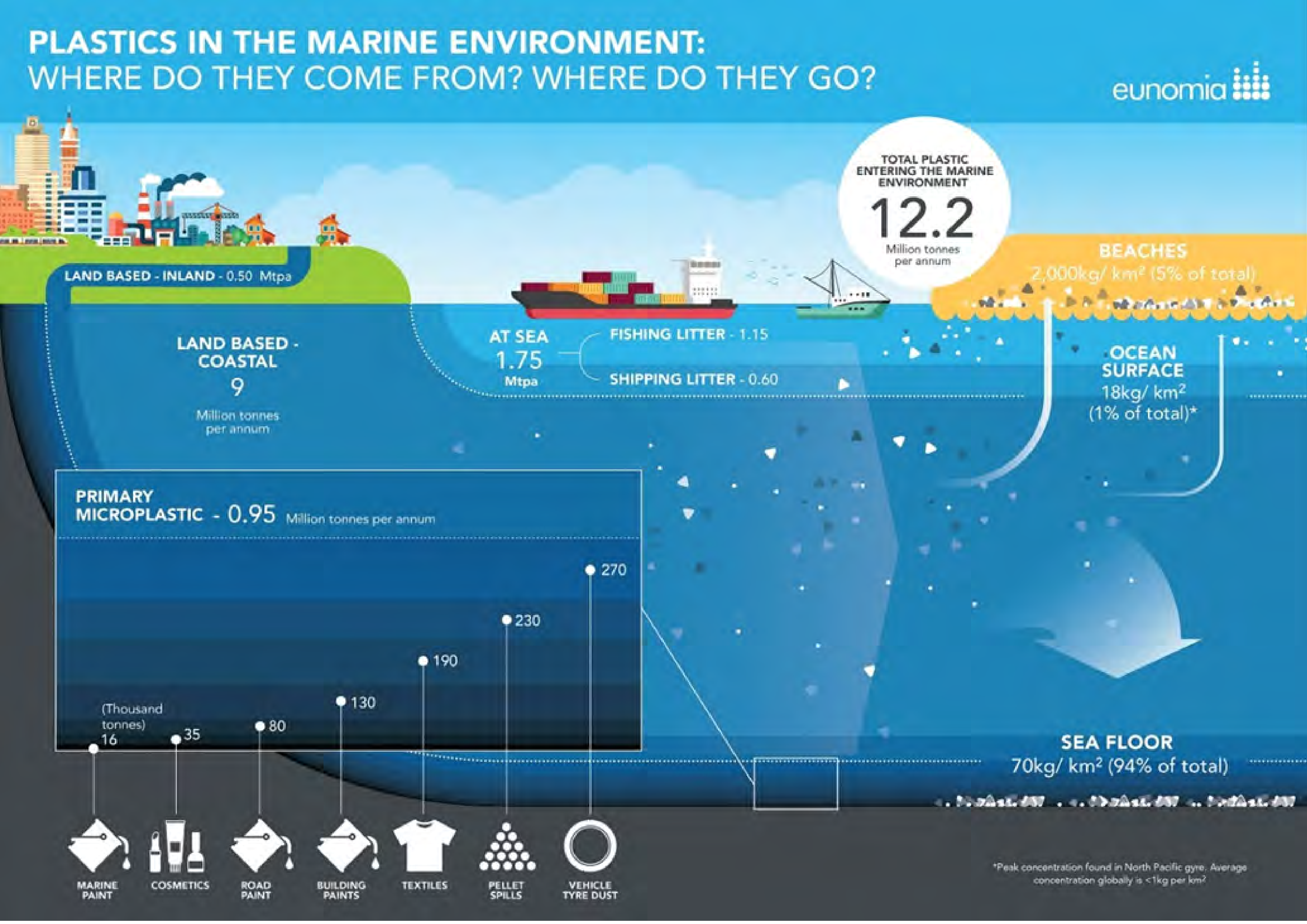
An excellent way to prevent marine litter is to avoid generating waste in the first place. For more information on best practices for waste minimization and prevention, see the *Prevention and Minimization* section.

Improving waste collection systems

Improving waste collection systems (e.g., by increasing collection coverage and efficiency) can help reduce the risk that waste will be improperly disposed of in waterways, accidentally swept downstream during storm events, or otherwise allowed to enter oceans. For more information on best practices for waste collection, see the *Separation, Collection, and Transportation* section. Exhibit 9.7 provides a case study of how Santos, Brazil improved waste collection to reduce marine litter.

Bolstering recycling efforts

By supporting the local recycling industry, cities can create demand for materials (especially plastics, which account for as much as 90 percent of marine litter) that might otherwise enter ocean-bound waterways (Basel Convention 2020). For more information on best practices for recycling, see the *Recycling* section.



Source: Eunomia.

Improving environmentally sound disposal of waste

If waste cannot be recycled, it should be managed and disposed of in an environmentally sound manner. It is important to have disposal options to limit or prevent illegal dumping or open dumpsites where waste can quickly be carried by the wind and end up in waterways and, eventually, the ocean. For more information on improving the disposal of waste, see the *Dumpsite Management* and *Sanitary Landfill* sections.

Despite advancements in marine litter removal technology, cleaning up marine litter remains a labor-intensive effort. Removal efforts are also costly and inadequate to fully address the marine litter challenge. As a result, the best way to address marine litter is to prevent it from entering the environment.

Key Resources for Marine Litter

Strategies to Reduce Marine Plastic Pollution from Land-Based Sources in Low and Middle - Income Countries (IGES and UNEP 2020)

Sources (NOAA 2019)

Plastics Policy Playbook: Strategies for a Plastic-Free Ocean (Ocean Conservancy and Trash Free Seas Alliance 2019)

Fighting for Trash Free Seas: Ending the Flow of Trash at the Source (Ocean Conservancy 2019)

Global Partnership on Marine Litter [UNEP Undated(a)]

Single-Use Plastics: A Roadmap for Sustainability (UNEP 2018b)

Exhibit 9.7 CASE STUDY

Santos, Brazil's Door-to-Door Separate Collection Scheme

When it comes to solid waste management, Santos faces challenges such as landfill closure, unavailable land for a new landfill, and low recycling rates. Given Santos' close proximity to Brazil's coastline, marine litter is also a primary concern.

In order to reduce litter entering the ocean, Santos set up Lixo Limpo in 1990, a program to collect dry recyclables along the beachfront. In 1995, the program was expanded to collect dry recyclables from the entire region. To further reduce marine litter, Santos established "Recicla Santos," which was codified into law in 2016. The program, which imposes fines on those who do not comply, implemented mandatory source segregation into wet and dry waste to improve collection. The door-to-door separate collection scheme collected 4,500 metric tonnes of dry recyclable materials between 2017 and 2018.

A key component of the separate collection scheme is separate regulations for small and large waste generators. Small waste generators (e.g., households and small businesses) must segregate dry and wet waste, which is collected by the municipality's regular door-to-door collection service. Large waste generators (e.g., those that produce up to 120 kilograms or 200 liters per day) must also segregate their waste. However, they are responsible for contracting the collection, transportation, and final disposal of waste from private providers. The municipality will collect their dry waste with prior authorization. Santos' partnerships with local institutions to educate community members on collection and separation have also been successful.

In addition to their source-separated, door-to-door collection scheme, Santos implemented "Cata treco," a program to collect bulky, construction, and demolition waste on demand to avoid inadequate disposal. The city estimated the program collected 36,646 metric tonnes of waste in 2017. "Cata treco" is part of a partnership that operates out of the municipal market and trains residents to use wood from discarded furniture. This program has reused approximately 3 metric tonnes of wood that would have otherwise gone to a landfill.

To learn more about these activities, see ***Santos: Setting the Scene of the Local Waste Management System*** (ABRELPE Undated).

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10 ORGANIC WASTE MANAGEMENT

Key Resources

- Municipal Solid Waste Knowledge Platform [CCAC Undated(a)]
- U.S. EPA Anaerobic Digestion Web Site (U.S. EPA 2020a)
- Biogas Sector Tools and Resources (GMI 2020)
- Technical Guidance on the Operation of Organic Waste Management Treatment Plants (CCAC and ISWA 2016b)
- Sustainable Financing and Policy Models for Municipal Composting (World Bank 2016)
- Toward Sustainable Municipal Organic Waste Management in South Asia (ADB and the Australian Government Aid Program 2011)
- Global Food Waste Management: An Implementation Guide for Cities (Jain et al. 2018)
- Reducing Food Loss and Waste: Setting a Global Action Agenda (Flanagan et al. 2019)
- Anaerobic Digester (AD) Project Screening Tool (CCAC 2018a)
- OrganEcs –Cost Estimating Tool for Managing Source-Separated Organic Waste (U.S. EPA 2016c)

Section 10

Organic Waste Management

Organic waste accounts for more than half of the solid waste stream in many low-income countries (Kaza et al. 2018). Many cities have found that diverting organic waste from disposal sites can lead to considerable health, economic, and environmental benefits. Organic waste management strategies such as composting and anaerobic digestion (AD), which involves using natural processes to turn organic content into biogas, are feasible options in most locations, but require careful planning and implementation.

This section provides an overview of the benefits of diverting organic waste from dumpsites and landfills, and best practices for organic waste management (including composting and AD).

What is Organic Waste?

Organic waste in the solid waste stream is generally divided into two categories:

- **Food loss and waste.** Food waste includes unused produce from pre-consumption sources (e.g., markets and restaurants) and food left over after consumption. Food loss includes unused products from the agricultural sector (e.g., unharvested crops).
- **Green waste.** Green waste includes waste from gardens, landscaping, and tree trimming.

Why Focus on Organic Waste?

In most instances, organic waste is collected and disposed of in dumpsites or landfills. This practice is concerning for several reasons:

- **Collection, transportation, and disposal costs.** Organic waste is generally very dense and has a high moisture content. Transporting large quantities of organic waste from points of generation to disposal contributes to higher fuel-consumption rates and higher fees at disposal sites.

Exhibit 10.1. What is organic waste?

- **Loss of nutrients.** Organic waste is a rich source of nutrients that could be used to enrich both urban forestry and agricultural land.
- **Impacts on disposal sites.** Leachate and gas management and structural shifting from organic decomposition are some of the most cost-intensive activities at disposal sites. Additionally, disposing of large quantities of organic waste in landfills reduces the operating lifespan of those facilities.
- **Environmental impacts on local air quality and climate change.** When organic waste decomposes it contributes to air, water, and ground pollution. For instance, when organic waste decomposes in anaerobic conditions it produces methane gas. Methane is a short-lived climate pollutant and a precursor to ground-level ozone, an air pollutant. Release of methane at landfills causes fires that result in both local air pollution and black carbon emissions that contribute to climate change. Leachate results in both water and ground pollution. Finally, decaying organic waste also causes odor problems.

In light of these impacts, many cities are adopting policies and programs to divert organic waste and use it as a resource. Organic waste, when separated properly, can be composted or processed in anaerobic digesters to create valuable products (e.g., compost, biogas, digestate) that cities can use or sell.

CASE IN POINT

Santa Juana, Chile's Source Separation Collection

More information is available on the ***Reciclo Orgánicos website*** (Reciclo Orgánicos 2020).

The Municipality of Santa Juana is the first municipality in Chile to have 100 percent coverage of source separate collection. The city has a composting and recycling facility with capacity to treat all the source-separated waste from households.

After the first year of operation, the amount of waste the city disposes at the landfill (a 100 kilometer distance) has declined by 30 percent, saving the city considerable fuel costs and gate fees.

Treatment Options

Organic waste treatment options are generally divided into two categories: composting and AD.

- **Composting.** Composting is the controlled decomposition of organic materials in the presence of oxygen. Composting requires three general steps: (1) combining organic waste types, such as wasted food, yard trimmings, and manure; (2) adding wood chips, shredded paper, or other bulking agents to accelerate the breakdown of organic waste; and (3) allowing the compost to stabilize and mature through a curing process (U.S. EPA 2015).
- **AD** involves the breakdown of organic materials by microorganisms in the absence of air. The products of the AD process include biogas, an energy source that contains mostly methane and carbon dioxide, and digestate. Digestate is the material that is leftover after organic materials are anaerobically digested. Digestate is rich in nutrients and can be used as fertilizer for crops.

Exhibit 10.2 illustrates how organic waste can be converted to organic fertilizer through composting and Exhibit 10.3 illustrates how AD transforms organic feedstocks into biogas and digestate that can be used in various ways. The design of anaerobic digesters varies based on operating temperature and type of feedstock used (U.S. EPA 2018a).

Exhibit 10.2. Illustration of a Composting System

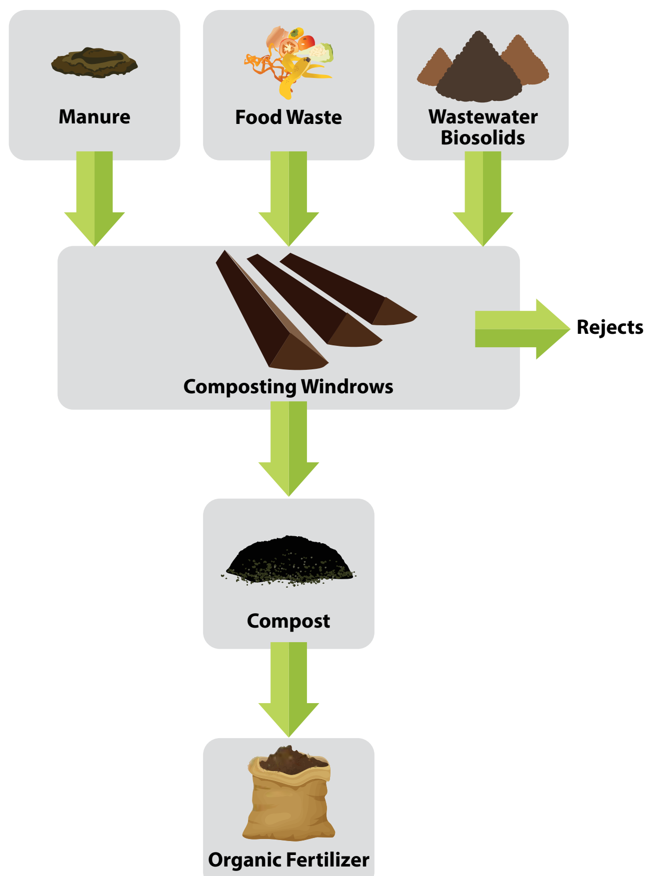
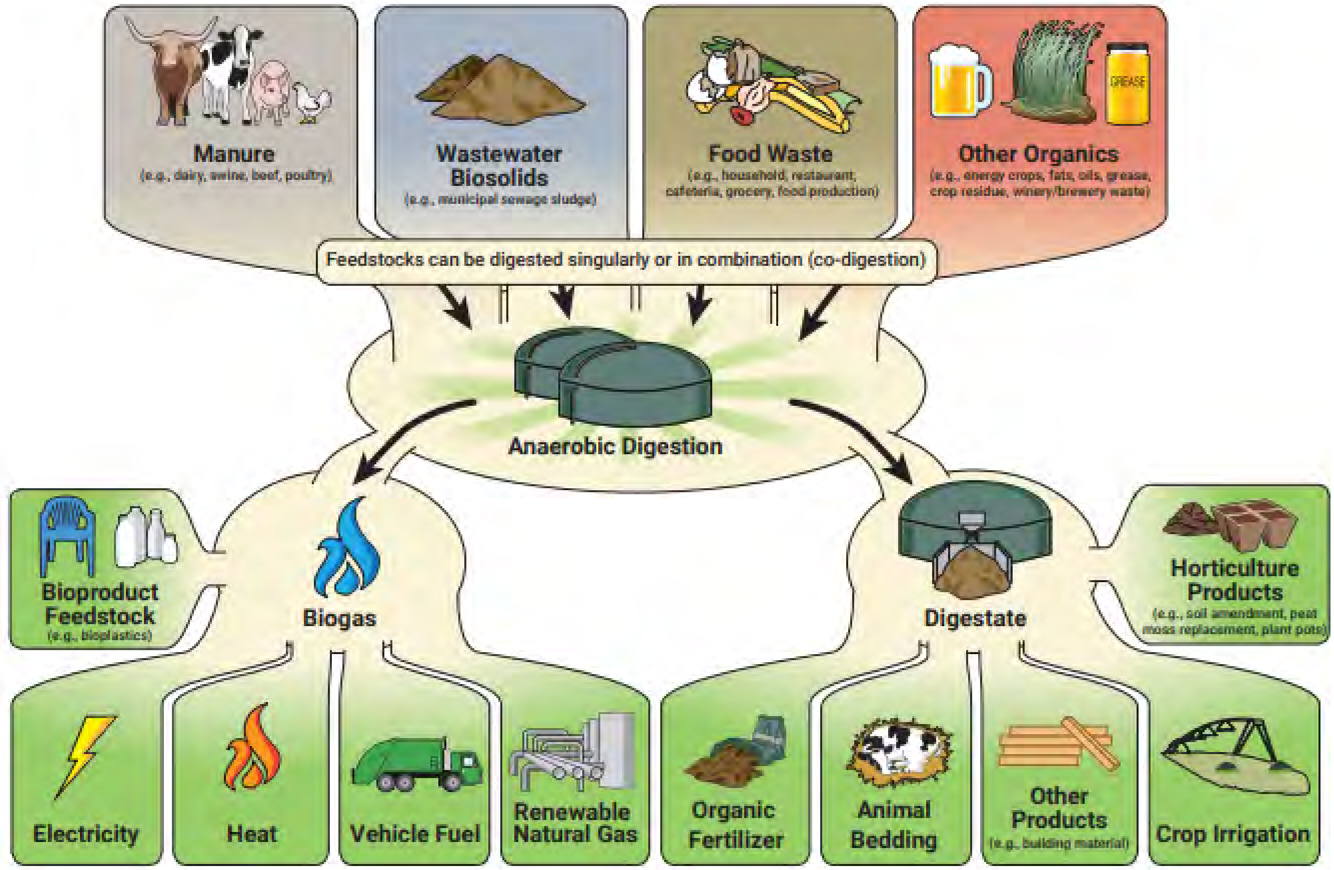


Exhibit 10.3. Illustration of an AD System, Showing Feedstocks and Byproducts (U.S. EPA 2018a).



Key resources at the beginning of this section provide more details on technologies and best practices for designing and operating facilities. For example, the World Biogas Association and C40 Cities produced an [*Implementation Guide for Cities*]() for food waste management (WBA/C40 2018). This guide provides step-by-step processes for evaluating and selecting organic waste treatment facilities.

Treatment Technology Co-Benefits
In addition to the general benefits of diverting organic waste from landfills, composting and AD can lead to a range of environmental and economic benefits. For example, the use of compost enriches soil, helps retain moisture, suppresses plant diseases and pests, and reduces the need for chemical fertilizers. AD minimizes odor, reduces pathogens and solid waste, and produces gas and digested materials (both wet and dry) that can be used for various applications (U.S. EPA 2016b). Biogas produced by AD can be used as a renewable fuel source for cooking, heating, cooling, transportation, and electricity. Digested materials left over from AD can be used as a soil amendment or fertilizer.

Project Scale
Organic waste can be treated in a centralized or decentralized manner, depending on local conditions and needs. Centralized models involve a large facility where waste is transported from multiple locations in a city or region. For example, some cities in India have large composting facilities near their current disposal sites (e.g., South Delhi, Coimbatore, Pune), and the City of Talca is building the largest compost facility in Chile at its landfill.

The decentralized model emphasizes processing and treating waste in proximity to where it is generated. For example, cities can support residents and businesses in setting up household-scale composting

CASE IN POINT

India's Solid Waste Management Rules

For more information, review the ***Government of India's Solid Waste Management Rules 2016*** (Government of India 2016).

India's comprehensive Solid Waste Management Rules of 2016 require that all waste generators, from street vendors to large commercial buildings, separate their waste into three categories: biodegradable, non-biodegradable, and household hazardous waste. The bottom line is that waste that is not separated will not be collected.

projects (e.g., by providing guidance on how to build a small compost bin). Cities can also establish smaller-scale facilities that receive organic waste from a limited number of households and businesses to either compost or treat in AD systems.

Many cities are moving toward decentralized organic waste treatment systems. The decentralized model has multiple benefits, including less fuel needed from reduced transportation of heavy organic waste and increased flexibility if part of the system breaks down. In a decentralized model there are multiple, small composting or AD facilities; and if one or more of those facilities is offline, waste can easily be diverted to another facility nearby. In a centralized system with a large facility, a shutdown can lead to waste piling up. Regardless of whether it is centralized or decentralized, it is important for every plant to have contingency plans if it breaks down.

In most instances, cities will benefit from establishing small-scale pilot projects that focus on collecting organic waste from sources where the risk of contamination from inorganic waste components is low. For example, it is typical to begin organic waste treatment projects by focusing on organic waste collected from produce markets, commercial-scale kitchens, or other locations where large quantities of organic waste are not contaminated with other wastes.

Best Practices

This section describes several best practices for managing organic waste, including collecting and analyzing data on organic waste, evaluating policy and program options for separating organic waste from the general solid waste stream, analyzing options for treating separated organic waste, and developing organic waste management projects.

Strategic Planning

The *Planning Systems* section discusses key steps in planning and evaluating a waste system. As part of their solid waste management system, cities can establish a formal organic waste management plan or program. While there are upfront costs to establishing an organic waste diversion program, cities can potentially reduce the costs of collecting and transporting waste for disposal (e.g., by organically treating waste in decentralized facilities, rather than transporting them long distances to landfills outside the city). As an added benefit, cities can potentially generate revenue from the products of organic waste treatment (e.g., compost, biogas). Steps for enacting an organic waste management include:

1. **Understanding the waste stream**. Organic waste diversion needs to be based on the type of waste generated and the source of the waste. The design of a diversion program therefore should depend on the results of a waste characterization, as described in the *Waste Characterization* section.

CASE IN POINT

São Paulo, Brazil's Organic Waste Management Strategy

For more information, review the ***Strategy for Organic Waste Diversion – Collection, Treatment, Recycling and Their Challenges and Opportunities for the City of Sao Paulo, Brazil*** (CCAC and ISWA 2016a).

The City of São Paulo developed an organic waste management strategy in 2016 to complement their pre-existing integrated waste management plan that is based on four pillars: the separate collection and transport of organic waste, the small-scale treatment of organic waste, communications with stakeholders, and the creation of economic instruments to motivate various actors. The strategy is tailored to the city's particular waste management practices and needs, and it presents a detailed approach for systematically building an organic waste management program from the bottom up.

2. **Enacting supporting policies**. Local policies, such as mandatory separation rules, can help drive organic diversion efforts. For more information on policies that cities have enacted to promote waste stream segregation, see the *Assessment of Separation Options* section below.

3. **Understanding technology options**. Treatment options will depend on the type of waste generated and other local conditions.

4. **Engaging stakeholders**. Communications and outreach are critical components of effective organic waste diversion programs, as it can help boost diversion rates. For more information on stakeholder engagement strategies, see the *Stakeholder Engagement* section.

5. **Ensuring quality**. The products, including the compost and digestate from organic waste treatment, have to be of high quality to ensure that they do not contaminate the land that they are applied on.

6. **Assuring safety**. There are a variety of hazards at treatment plants, including mechanical, explosions, and fire.

Data Collection and Analysis

Understanding the quantities, types, and sources of organic waste in the waste stream is critical for identifying and selecting effective policies and technologies to divert that waste, treat it, and use it as a resource.

The *Waste Characterization* section presented best practices for conducting waste characterization studies to map quantities, types, and sources of waste in general. These studies can provide helpful information to begin identifying potential organic waste management options. In addition, cities can conduct more detailed analyses of organic waste to better plan and design broader diversion strategies, and individual organic waste management projects. For example, many cities have conducted analyses to identify businesses, institutions, and facilities that generate large quantities of organic waste. These sources are often the first ones that cities target for organic waste management pilot projects. Locating compost or AD facilities near these large generators can reduce waste transportation costs.

Assessment of Separation Options

After a city collects data on sources of organic waste, it must determine the most-appropriate means of encouraging or requiring residents, businesses, and institutions to separate organic materials from the general waste stream. Separating organic and inorganic fractions of the waste stream minimizes the risk of contamination in compost; contaminated compost is very difficult for cities to sell and is inadvisable to use. Separating organic waste from inorganic waste is also important for AD projects, since clean organic feedstocks help ensure optimal digester efficiency.

Separation strategies often include:

- **Separation mandates.** Many cities require certain segments of the population to separate the organic fraction of their waste. These mandates can be applied to all waste generators or targeted at certain types of entities (e.g., large-scale, organic waste generators; large, new housing development projects). The *Separation, Collection, and Transportation* section provides more detail on separation mandates and how they are implemented through separate waste collection programs.
- **Bans or fees on organic waste disposal.** Some cities have implemented economic penalties and incentives, including bans on future disposal of organic waste in dumpsites and landfills, increased tipping fees on organic waste to encourage businesses and collection companies to divert these materials for treatment, and reduced collection fees for households segregating waste correctly.
- **Organic waste diversion targets.** Similar to bans on organic waste disposal, some cities use diversion targets (e.g., reducing the amount of organic waste disposal by a certain future year) to help guide decision-making about solid waste management programs and projects.
- **Voluntary programs.** Cities can establish incentive programs or challenges to encourage residents, businesses, schools, and other participants to segregate their waste.

Selection of Treatment Technologies

When selecting technologies to treat separated organic waste, cities typically consider a range of technical and financial factors, including:

- **Technical considerations** include quantities, types, and sources of organic waste to be treated; the size and operating capacity of a potential treatment facility; the quantity of end products (e.g., compost or biogas) to be sold or used; and any relevant standards or certifications required for those products.
- **Financial considerations** include capital costs associated with building the facility, operating costs to maintain it, revenues from selling its products, and marketing plans for selling products to targeted buyers. Cities can use tools such as the *OrganEcs model* (U.S. EPA 2015c) developed by the CCAC Municipal Solid Waste Initiative to estimate the costs of composting or AD projects for treating organic waste.

Cities often conduct feasibility studies to analyze these factors, identify potential challenges (see Exhibit 10.4), and determine whether and how a project should be developed. Well-prepared studies (e.g., with high-quality data and careful documentation of assumptions) can help cities secure support from financial institutions and private sector partners.

Questions for Decision-Makers

- Where are large-scale generators of organic waste located and what types of waste are generated, and will there be a sustained feedstock for treatment facilities?
- What separation strategies make the most sense, given the city's organic waste diversion objectives?
- What infrastructure and support will affected entities need from the city to ensure organic waste is separated successfully?
- What is the market for the products resulting from treatment, including compost, biogas, and digestate?

CASE IN POINT

Composting in Dhaka, Bangladesh

For more information, review ***C40 Good Practice Guides: Dhaka – Composting Project*** (C40 Cities 2016a).

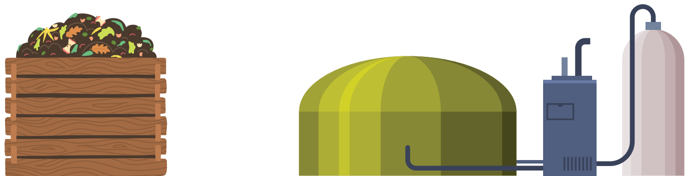
Waste Concern, a nongovernmental organization based in Dhaka, has been operating composting projects in Bangladesh since 1995. Initially the organization struggled to sell the compost they were producing, primarily due to strong competition from chemical fertilizer companies. To address this challenge, the organization worked to ensure that their compost meets the highest-quality standards and now sells their compost to fertilizer companies, who then sell it to farmers as a soil amendment to complement chemical fertilizers.

Several tools are available to assist cities in conducting technical and financial feasibility assessments of organic waste management projects. Organizations such as the CCAC Municipal Solid Waste Initiative and the Global Methane Initiative offer collections of such tools, such as the *Municipal Solid Waste Knowledge Platform: Tools* [CCAC Undated(b)] and *Tools and Resources* [GMI Undated(a)] for biogas projects.

Questions for Decision-Makers

- What size project makes the most sense, considering the local demand for products and availability of feedstock?
- What technologies makes the most sense, given the city's specific needs and capabilities?
- How will the city ensure a dedicated stream of quality feedstock?
- How will the city ensure effective operations and maintenance of facilities at full capacity?
- What processes and procedures will the city put in place to ensure their compost meets quality standards, or their AD system generates optimal quantities of high-quality biogas and digestate?
- How will the city market the products (e.g., compost and biogas) to potential end users?

Exhibit 10.4. Common Organic Waste Treatment Challenges and Potential Solutions

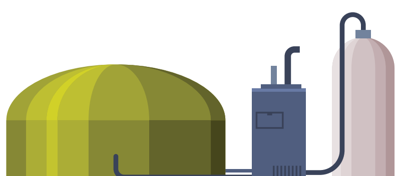


Composting and Anaerobic Digestion (AD)

Challenges	Potential Solution
Operations hazards and occupational risks	Providing quality assurance systems and training
Substantial capital and operating costs	Considering cost-recovery mechanisms, including charging collection fees that are specific for organic waste Avoiding excessive capital costs by using small, decentralized composting facilities at the neighborhood scale

Composting

Challenges	Potential Solution
Limited demand for compost from end users	Selling compost to fertilizer companies that can market the compost with other products Using compost on public lands for landscaping, soil amendment, or erosion-control projects Conducting outreach to local farmers who can use the compost Working with national governments to create enabling environments that increase demand for compost (e.g., adopting quality standards, mandating that fertilizer companies purchase and market a certain percentage of the compost)
Low-quality compost/ contamination	Securing feedstock from locations that produce pure organic waste streams that are easily separable (e.g., produce markets) Communicating continuously with stakeholders about acceptable types of organic waste (see Exhibit 10.5) Following established technical guidelines for maintaining optimal operating conditions Providing thorough and ongoing training opportunities for facility staff



AD

Challenges	Potential Solution
Low/inconsistent biogas production	Ensuring an optimal mix of feedstocks to maximize biogas generation potential (e.g., using the *AD Project Screening Tool* (CCAC 2018a))
System malfunction	Securing feedstock from locations that produce pure organic waste streams that are easily separable (e.g., produce markets) Following established technical guidelines for maintaining optimal operating conditions Providing thorough and ongoing training opportunities for facility staff

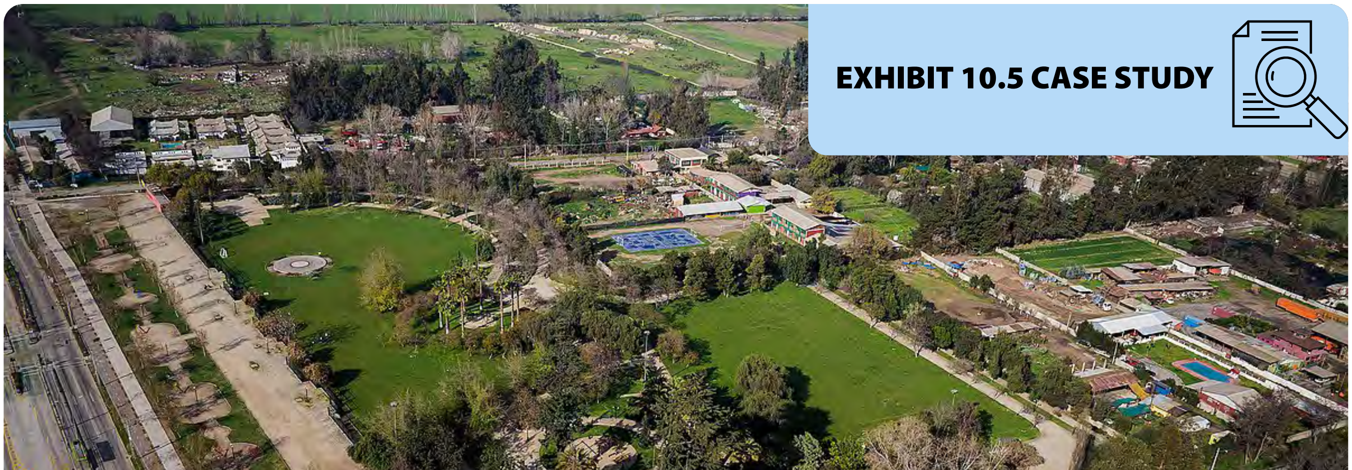


EXHIBIT 10.5 CASE STUDY

Credit: Gobierno de Chile

Separating and Recycling Organic Waste in La Pintana, Chile

La Pintana conducted a waste characterization study and determined that vegetable waste contributed the largest portion of the city's solid waste stream. In order to manage this waste appropriately, the government decided to start a composting program built on existing infrastructure and other local resources. Residents of La Pintana receive 35-liter bins, and local college graduates in environmental fields conduct door-to-door outreach campaigns to teach residents the importance of separating out vegetable waste. The system for collecting separated waste was built on existing routes, and did not increase the number of waste collection trucks or costs. The collected vegetable waste is transported to a treatment plant where it is composted. The plant includes a compost area that can process about 18 metric tonnes of waste per day and a vermiculture area that can treat an additional 18 to 20 metric tonnes of waste per day (Allen 2012).

Approximately 35 metric tonnes of vegetable waste are collected each day from households and street markets in La Pintana. The waste diverted from landfilling saves the city approximately 700 U.S. dollars per day in transportation and disposal costs. Additionally, the compost produced by vermiculture can be sold for 40 U.S. dollars per kilogram (OECD LEED Programme 2014). This new system operates at a lower daily cost than the former one (when all waste was landfilled), saving La Pintana money while generating social and environmental benefits.

To learn more about La Pintana's composting activities, review ***Chile´s Pathway to Green Growth: Measuring Progress at Local Level*** (OECD LEED Programme 2014) and ***La Pintana, Chile: Prioritizing the Recovery of Vegetable Waste*** (Allen 2012).

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11 RECYCLING

Key Resources

- What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050 (Kaza et al. 2018)
- Overview of Legal Framework for Inclusion of Informal Recyclers in Brazil (Dias 2011)
- Recycling and Disposal of Municipal Solid Waste in Low and Middle-Income Countries (UN-Habitat 2011)
- A New Circular Vision for Electronics (WEF 2019)
- ISO Standards for Recycling (ISO 2020)
- Materials Recovery Facility Toolkit (ADB 2013)

Section 11

Recycling

Although recyclables account for only 16 percent of solid waste generated in low-income countries, the amount of waste generated and the fraction of waste that is recyclable typically increase as economies improve (Kaza et al. 2018). By collecting and separating these materials out of the waste stream, many cities have preserved landfill space, generated revenue, and provided employment for residents. Recycling not only saves money for cities but also helps the environment by reducing the energy and natural resources needed to create new products, and helping prevent the flow of waste into waterbodies.

This section provides information on the benefits of recycling, the most common types of recyclable material, challenges of operating a successful recycling program, and best practices for planning and implementing recycling programs.

What Is Recycling?

Recycling refers to collecting and processing materials that would otherwise be disposed of as waste and turning them into new products. Cities can benefit from recycling programs in the following ways:

- **Reducing waste disposal costs.** Recycling reduces the amount of waste sent to landfills, thus extending the lifetime of those facilities; and reducing the costs of siting, building, and operating new facilities.
- **Reducing environmental impacts.** In many developing countries, uncollected waste is burned in the open to reduce its volume. Reducing the amount of recyclable material that is openly burned improves air quality and reduces greenhouse gas emissions. In addition, increasing recycling rates helps prevent waste from turning into marine litter, especially in coastal areas.
- **Reducing the use of virgin materials.** Slowing the extraction of virgin raw materials conserves natural resources such as timber, water, and minerals, while increasing economic security by using a domestic source of readily available materials.
- **Strengthening economic growth and social equity.** Recycling creates employment and offers the local population a source of income. Formal recycling programs supported by some cities have served as a way for informal sector workers to become formal solid waste management staff, improving their health, security, and working conditions.

While many items can be recycled, the most common include:

- **Paper**. Paper can be recycled to produce more paper and paper-related products. In addition, the fibers from recycled paper can be turned into other marketable products such as tape, bandages, or insulation. However, paper is not recyclable indefinitely because its fibers shorten with each use.
- **Aluminum**. Aluminum is an ideal material because it can be recycled multiple times without losing its quality and typically has a higher economic value. Producing recycled aluminum saves more than 90 percent of the energy associated with making new aluminum (Aluminum Association 2019).
- **Steel**. Steel cans are the most common household steel recycled; however, scrap steel of all types can be recycled. Steel may be the most recycled commodity worldwide and is used by manufacturers to produce a wide variety of products such as building products and vehicles. Recycling steel cans can save between 60 percent and 74 percent of the energy required to produce new cans from raw materials (U.S. EPA 2016a).

- **Plastics**. In 2016, plastics represented 12 percent of solid waste worldwide (Kaza et al. 2018). Plastics can take hundreds to thousands of years to decompose, which presents major environmental and human health problems. At the local level, some types of plastic (e.g., high-density polyethylene and polyethylene terephthalate) can be recycled into a variety of items, including plastic lumber, furniture, cement blocks, asphalt for roads, and household goods (e.g., containers, baskets, mats).

- **Batteries**. Alkaline batteries, which are used in many common household applications (e.g., flashlights), are recycled in many facilities. Lead-acid batteries contain heavy metals and should be recycled in facilities with proper air pollution control equipment. Lithium-ion batteries are becoming an increasingly popular means of energy storage. They can be recycled, but should be collected and handled separately because they can explode under pressure and cause fires. See the *Identification of Special Wastes* section for more information.

- **Glass**. Glass is another material that maintains its quality and does not wear out over time. Glass bottles and jars can be remanufactured into new glass containers. They can also be reused as storage containers without undergoing the remanufacturing process.

- **Used motor oil**. Used motor oil can be turned into lubricants, processed into fuel oils, or used as raw materials for other steps in the oil refining industry. Motor oil recycles well because it does not wear out; it only needs to be purified for reuse. Used motor oil recycling is most effective when this material is collected separately.

- **Tires**. Separately collected tires can be used in many different applications depending on the market. They can processed and used in roadways as an alternative to gravel, baled for civil engineering uses, or even shredded and used as liners and covers for landfills. In some countries, tires are used as fuel in incineration facilities. It is important to understand the end use before processing scrap tires. There are some environmental concerns with this process, but tire-derived fuel is more efficient than other types of fossil fuels (U.S. EPA 2016e).

- **Electronic waste (e-waste)**. E-waste generally includes waste materials that include electrical or electronic components, including phones, computers, appliances, and other materials. Many of these can be recycled if handled appropriately. According to a 2019 report by the World Economic Forum (WEF 2019), global e-waste is worth more than $60 billion annually. Building systems to recover materials from these products is a priority area of focus for many countries.

The value of the recycled material is highly variable and depends on the country and the market for it. Additionally, data on the value of items that can be recycled are not complete in many countries, making the value difficult to estimate.

Challenges

Although recycling saves resources and energy, cities often struggle to implement a successful recycling program for a variety of reasons, including:

- **Quality.** Recyclables must meet specific quality thresholds in order to be turned into new products, which requires careful sorting and treatment. For example, different types of plastics have unique properties that make them more or less suitable for recycling. If higher-quality plastics are not separated from lower-quality plastics, the entire quantity of plastics can only be used to produce products for which the lower-quality plastics are suitable. The *International Organization for Standardization* (ISO, 2020) provides standards for recycling materials. Following these standards can help ensure quality.

- **Contamination.** Recyclables are considered contaminated when non-recyclables have not been completely separated out (e.g., if lithium-ion batteries, which can cause fires if not handled separately, are left in electronics). Recyclables can also become contaminated when items are not cleaned properly (e.g., food residue is still

CASE IN POINT

Tunisia's Recycling Program

In 1997, Tunisia launched the Eco-Lef recycling program to address the country's plastic waste problem. A major component of the program is its extended producer responsibility principle in which packaging producers are responsible for the treatment and disposal of post-consumer products. Extended producer responsibility helps create a financially sustainable system that encourages informal sector workers to collect recyclable materials and deliver them to Eco-Lef collection centers. Waste collectors are paid more for bringing items to an Eco-Lef collection center. Prices for plastics at a center are approximately 200 dinars more per ton than in a traditional marketplace (Kaza et al. 2018). When the Eco-Lef program was nationally implemented, individual cities have seen job growth, increased incorporation of the informal sector, and reduced plastic waste.

on the item when it enters the recycling stream) or through the dispersion of additives such as phthalate. Contamination often leads to an entire batch of recyclables being sent to a landfill instead of being recycled. Contamination from non-recyclable materials may also cause machinery used in the recycling process to malfunction.

- **Volatile markets.** The demand for recyclables can shift unpredictably, resulting in price fluctuations. In some instances, sudden drops in material prices can make operating recycling facilities unsustainable. In such cases, recyclables may end up being disposed of in landfills.
- **High operating costs.** Recycling operations can involve high costs for labor and material transportation. In locations where these costs are high, recycling lower-value materials is often not profitable.
- **Financing for capital investments.** As with any infrastructure projects, building recycling facilities typically requires external financing. For more information on financing waste sector projects, including using extended producer responsibility schemes to offset recycling costs, see the *Economic Considerations* section.
- **Lack of processing facilities.** Infrastructure can be a major barrier to implementing recycling programs. Many cities are not equipped with material recovery facilities (MRFs), or there may be a lack of industries or markets to turn recycled materials into products.
- **Lack of appropriate technology.** Some items cannot be recycled without advanced technology (e.g., single-use plastics). If these items enter the recycled material stream, they can get caught in machinery and damage the sorting equipment. These items often end up in landfills or as marine litter.
- **Environmental and health concerns.** Transportation and processing of recyclable materials can lead to increased air pollution. Recycling can also lead to increased water use to ensure items are not contaminated. Some materials are very dangerous when not appropriately handled (e.g., lithium-ion batteries can explode and cause fires). These environmental impacts need to be weighed against the environmental gains of recycling.
- **Incorporation of the informal sector.** It It is not always easy to incorporate the informal sector since it often displaces intermediaries who have long been in the business of recycling. Cities also have limited budgets and may not be able to incorporate the informal sector into their payrolls. See the *Informal Sector Recycling* section for information on engaging with the informal sector.

Best Practices

This section identifies best practices for planning and implementing recycling programs, including planning, collecting, separating, processing, sorting, and selling recyclable materials for remanufacturing.

Strategic Planning

Many cities have found it helpful to establish a formal recycling plan or program; for examples, see the *Municipal Solid Waste Knowledge Platform: Cities* [CCAC Undated(a)]. Recycling plans typically establish how the city will meet their recycling objectives through the adoption and implementation of various policies, programs, and projects. While there are upfront costs for establishing a recycling program, cities can potentially save money overall by reducing the costs of collecting and transporting materials; and reducing the need for larger, new landfills or incineration facilities. Steps for establishing a formal recycling plan include:

1. **Understanding the recycling stream**. Recycling plans need to be based on the type of material generated and collected, and will therefore depend on waste characterization, as described in the *Waste Characterization* section.

2. **Conducting market research**. Cities have found it useful to collect and analyze data on the size of the local market for recyclable materials. Key considerations include how far away the nearest recycler or remanufacturing facility is located, who would bear the costs of transporting materials to that facility, and the volatility of market prices for different materials.

3. **Enacting supporting policies**. Local policies, such as mandatory separation rules, can help drive recycling efforts. These policies can also help reduce the risk of contamination of the recycling stream. For more information on policies that cities can enact to promote waste stream segregation, see the *Separation, Collection, and Transportation* section.

4. **Engaging stakeholders**. Communications and outreach are critical components of effective recycling programs, as they help increase public participation in segregating recyclables at the household level, reduce the risk of contamination in the recycling stream, and can help boost recycling rates. For more information on stakeholder engagement strategies, see the *Stakeholder Engagement* section. See Exhibit 11.3 for a case study on engaging independent recyclers.

For more information on establishing recycling programs, see UN-Habitat's (2011) guide, *Recycling and Disposal of Municipal Solid Waste in Low and Middle-Income Countries*.

Collecting and Separating

Recyclable materials can be collected and separated by generators, collectors, or via dedicated communal bins (see the *Separation, Collection, and Transportation* section). Recyclables separated by generators tend to be higher quality than recyclables separated from mixed waste; however, separation at

Questions for Decision-Makers

- What are the city's objectives for establishing a recycling program? Is it to divert waste from landfills, prevent marine litter, or promote economic growth?
- How can the city ensure clean, high-quality streams of recyclables with little contamination?
- What role can the informal sector play in separating and processing recyclables?
- Are there private sector partners the city can engage (e.g., firms that have corporate social responsibility or extended producer responsibility targets)?
- What are the best methods of communicating with stakeholders about recycling efforts?
- What is the market for recyclable materials? How would the city adapt to drops in material prices?
- Is there existing infrastructure that can be used to facilitate recycling (e.g., unused spaces that can be adapted to serve as recycling facilities)?
- Is there adequate labor available to operate recycling facilities in a cost-effective manner?

CASE IN POINT

Brazil's National Solid Waste Policy

The government of Brazil passed a law in August 2010 to establish the Brazilian National Policy on Solid Waste. This legislation aims to better integrate and involve informal sector workers in the recycling process, and to provide incentives for local agencies to develop organizations for informal sector workers. Through the creation of a solid waste plan, Brazil aims to close and recover dumping sites, which will also provide social and economic benefits to informal sector workers. The law requires waste management services to prioritize the recruitment, organization, and functionality of informal sector workers.

For more information, see the ***Law No. 12305 – Brazilian Policy on Solid Waste*** (Brazilian NR 2010)..

the home or a business requires diligent effort on the part of generators. Communications and outreach are therefore essential factors in successful recycling collection programs, especially if a city is trying to encourage generators to separate recyclables. See the *Stakeholder Engagement* section for more information on stakeholder engagement strategies.

Communal bins are used in many cities. Cities have found it important to conduct outreach and provide clear instructions regarding what can be recycled and in what bin, which helps avoid contamination. See the *Separation, Collection, and Transportation* section for more information on communal bins.

Separation of recyclables is often performed by informal sector workers outside homes, at transfer stations, and at disposal sites. Incorporating informal sector workers into the formal collection process provides them with employment benefits while utilizing their experience. For detailed information on collection and separation, and incorporating the informal sector workers, see the *Separation, Collection, and Transportation* section.

Processing and Sorting

After collection and separation, recyclable materials are transported to a processing facility. At this facility, recyclables are sorted according to material type, cleaned of contaminants, and prepared for transport to a milling facility to break down the material or to a manufacturing facility if no further processing is needed.

MRFs are specifically designed to sort and recover recyclable materials. They can be located at a transfer facility or a standalone location. MRFs employ a combination of technologies to sort recyclables. Common technologies include rotating-cylindrical screens that separate materials according to size, overhead magnets to collect items containing iron or steel, and conveyor belts that move materials slowly past teams of workers who remove recyclable items. Although high-technology MRFs are not common in developing countries, many cities use smaller-scale facilities to coordinate the separation of recyclable materials by using lower-technology solutions, such as hand sorting (see Exhibit 11.1).

Some MRFs that process recyclables use intermediaries who buy recyclables from informal sector workers and sort, clean, and package them before sending them to the facility. Informal sector workers often have arrangements to sell recyclables to middlemen in exchange for some item or service (e.g., an intermediary lending the worker a cart).

Exposure to dust and other contaminants is a concern for workers at MRFs and other recycling facilities, so cities have found it important to have proper ventilation in the facility and provide personal protection equipment (e.g., dust masks, gloves) for workers.

Selling Materials for Remanufacturing

After all necessary processing has been completed, recyclables are made into new products at a recycling plant or other facility, such as a paper mill or bottle manufacturing facility. While cities typically do not remanufacture products, they can play a role in helping to ensure that the quality of the materials meet the standards of remanufacturers. Exhibit 11.2 provides an example of how some cities are using waste banks to coordinate efforts to sell recyclables.

Exhibit 11.1. Hand Sorting Recyclables at a Facility in Pune, India

EXHIBIT 11.2 CASE STUDY

Using Waste Banks to Process Recyclables in Indonesia

In Indonesia, many cities have adopted the "waste bank" model to organize their recycling efforts. Waste banks are decentralized, small-scale waste processing facilities where local residents can bring their recyclable materials and receive payment based on materials' daily market value. Residents who choose to participate are typically given a "bankbook" that is used to record "deposits." Participants can save their earnings at the bank or cash them out.

Waste bank staff – who are typically local residents – receive, separate, and bundle recyclable materials to be sold to recyclers. At some waste banks, staff use processing equipment to turn the recyclable materials into new products. For example, at one waste bank in Jakarta, staff operate shredding equipment to turn plastic bottles into flakes that are sold to recyclers at a higher price than intact bottles (see photograph above). Many waste banks also employ staff who turn recyclable materials into crafts for sale.

The waste bank model in Indonesia has grown in popularity in recent years, especially in response to the growing awareness about the benefits of increased recycling rates for preventing marine litter. As of 2018, more than 2,800 local waste banks were operating in the country. Many of these banks are supported by private companies, such as Unilever.

For more information, see ***Unilever Indonesia's Environment Program website*** (Unilever, Undated).

EXHIBIT 11.3 CASE STUDY

Independent Recyclers in Ho Chi Minh City, Vietnam

Independent waste collectors play an important role in Ho Chi Minh City's solid waste management system by collecting recyclables from practically inaccessible neighborhoods. Their work reduces the quantity of recyclables in landfills and decreases the cost of waste collection for the municipal government. Despite these environmental and economic benefits, independent waste collectors still lack necessary occupational health gear.

The United States Agency for International Development partnered with the Environnement et Développement du Tiers-Monde to strengthen Ho Chi Minh's solid waste management system by supporting independent waste collectors. They provided training to existing collector cooperatives and created a network of cooperatives to more effectively advocate for higher wages, protective health gear, access to health insurance, and city acceptance of motorized tricycles used in collection.

Since the program began, the cooperative network has advocated on behalf of 1,561 independent waste collectors. The program has also seen increases (from 0 to 22 percent) of women in cooperative leadership roles, in health care (815 workers gained better access), and occupational protective gear (1,200 workers were provided gear); and awareness-raising activities (8,700 community members participated). Additionally, independent waste collectors' monthly wages increased by about 65 percent through a $1 increase in fees paid by households.

To learn more, see the United States Agency for International Development's ***case study on Reducing Mismanaged Plastic Waste Through Healthier Waste Entrepreneurs*** (USAID 2019b).

Informal Sector Recycling

The informal recycling sector exists in most cities in developing countries. It consists of individuals, groups, and small businesses that perform peripheral collection and sale of recyclables and reusable materials. The sector may fill a gap where disposal, collection, or segregation options are lacking. Informal sector workers often operate in unsafe conditions, without employment benefits accorded to those in formal employment, and experience income disparity. Entire families, including young children, may participate in recycling activities and depend on it as a sole source of income. Informal sector workers are often marginalized by society and may be referred to by unfavorable terms, including "scavengers," "rag pickers," and "waste pickers."

How Does the Informal Recycling Sector Work?

Informal recycling workers earn income by selling the recyclables they collect to a network of dealers and industries (Wilson et al. 2009, Aparcana 2017). In some cases, workers may sell to other informal sector workers that reuse the material to be part of another process or product (e.g., scavenged parts to repair equipment). Recycling by informal sector workers happens at multiple locations:

- **Households.** Informal sector workers may have regular routes where they collect or purchase recyclables (e.g., paper, metal, clothing) from residents. This practice is more common where collection by the local authorities is infrequent or irregular; the informal sector plays the role of waste collector.
- **Community collection bins and transfer stations.** In the absence of a formal recycling program, community collection bins and transfer stations are a rich source of material for informal recycling workers.
- **Dumpsites.** It is common for informal recycling sector workers to recover material directly from dumpsites. Unlike sanitary landfills, dumpsites in developing countries often lack fencing or walls to prevent entry.

What Risks are Informal Sector Workers Exposed to?

Informal recycling sector workers are exposed to numerous risks that impact their health, wellbeing, and livelihoods. These risks include dangerous working conditions that can lead to physical injury, and exposure to toxins and other materials that can cause chronic illness. In addition, informal sector workers are often exploited because of their willingness to work for low pay, which exacerbates their existing socioeconomic vulnerability. Risks include:

- **Dangerous working conditions.** Informal recycling sector workers rarely have personal protective equipment such as gloves, masks, or proper footwear. Workers are exposed to sharp objects like metal and glass, hazardous wastes, or even medical wastes. Working at dumpsites is particularly dangerous when the waste in not properly compacted and can shift and cause slope failures, akin to avalanches of waste. There are documented incidences of informal sector workers perishing in slope failures. Informal sector workers are often in close proximity to large equipment (e.g., excavators and bulldozers), and are at risk of injury when the operators of those machines do not see them (Exhibit 11.4).
- **Fires.** Spontaneous fires may occur at dumpsites due the presence of methane from decomposing

Exhibit 11.4. Informal Sector Workers in Close Proximity to an Excavator in Addis Ababa, Ethiopia

organic matter. More often, waste is set on fire by members of the informal recycling sector to recover high-value recyclables such as metals. Fires are associated with both human health and environmental impacts.

- **Health impacts.** In addition to immediate physical harm from dangerous working conditions and fires, informal sector workers are exposed to disease vectors (e.g., rodents, insects), human health pathogens, and pollutants. Air pollution, such as particulate emissions from open burning of waste and landfill fires, affects the health of workers and neighboring residents.
- **Exploitation.** The informal sector workers lack the protection afforded to the formal sector workers by rules and regulations, and are often exploited by middlemen who buy recyclables from them.
- **Price variation.** The market for recyclables is volatile. Price swings contribute to the vulnerability of workers, many which already face extreme poverty.

What are the Advantages of Incorporating the Informal Recycling Sector?
In addition to reducing the risks that informal sector workers are exposed to (see previous section), cities can benefit from incorporating these workers. Bringing informal sector workers into formal employment takes advantage of their experience, improves their working conditions, and improves a city's employment statistics. Key advantages include:

- **Technological advantages.** Informal sector workers often introduce new and innovative technologies, such as developing phone applications for on-demand recyclables pickup.
- **Environmental advantages.** Informal sector workers achieve high recovery rates because collection is vital for their livelihoods. These increased recovery rates keep waste out of waterbodies and other critical habitats.
- **Economic advantages.** The informal recycling sector converts waste into tradeable commodities, forms new trading networks and businesses, and generates employment.
- **Social advantages.** Informal waste collectors' exposure to hazards are lessened when integrated into the formal system. Local employment figures are also improved by bringing them into the formal sector. In some places, informal sector workers receive education and training benefits as part of their integration into the formal recycling system.

Best Practices

There are a number of best practices to integrate the informal recycling sector and affiliated organizations into the formal waste management system, including:

- **Collect information**. Cities can collect information on informal sector workers' demographics, resources, organization, and practices to help inform decisions about how best to engage with these individuals.
- **Conduct inclusive outreach**. It is a good practice to involve and engage informal recycling workers in solid waste management planning and activities. Such engagement can help to identify solutions, generate buy-in, and ideally incorporate informal recycling sector workers into the formal workforce to preserve and improve their livelihoods. In addition, in many cities the informal sector brings long-established and elaborate networks of collectors, sorters, transporters, brokers, processors, and, in some cases, end markets for recyclables. Cities that proactively engage with the informal sector can collaboratively develop structures for working together to formalize recycling activities, while minimizing disruption to these pre-existing networks. The principles of stakeholder engagement are described in the *Stakeholder Engagement* section.
- **Create policies**. Policies can be developed and implemented at local and national levels to integrate the informal sector. Brazil and India have implemented national policies to require local government agencies to incorporate the informal sector in their waste collection and recycling activities.

CASE IN POINT

Incorporating the Informal Sector in Solid Waste Management Activities in Dakar, Senegal

For more information, see ***Women in Informal Employment: Globalizing & Organizing*** (WIEGO 2019).

The Mbeubeuss dumpsite in Dakar is the largest open-air waste dumping site in West Africa and has thousands of informal waste collectors (ILO 2019). Bokk Diom, the association of informal sector workers at Mbeubeuss, has worked to increase their membership since 2018. In addition, the organization established a Women's Bureau of Bokk Diom that has increased women's participation to 65.6 percent of all membership (WIEGO 2019). Furthermore, the group has focused their training sessions on safety and environmental impacts.

A key factor in Bokk Diom's success is their relationships with state, national, and municipal public officials, which leads to regular interactions between the informal sector workers and decision-makers. The group has also formed partnerships with national organizations such as Zero Waste Senegal.

- **Offer training.** Members of the informal recycling sector may require training to successfully integrate in the formal waste management sector. For example, they may benefit from health and safety training to improve their workplace behaviors, such as knowing what do to if they come into contact with medical waste. Living on the margins of society, members of the informal sector may not feel empowered to negotiate with waste generators, government agencies, or the middlemen who buy their recyclables. Therefore, training is critical to increase their negotiating power.
- **Engage cooperatives**. Informal sector workers in some cities have formed cooperatives and entered into contracts with the local government to collect waste. In India, SWaCH, a wholly owned workers' cooperative, conducts door-to-door collection under a contract with the Pune Municipal Corporation.
- **Involve nongovernmental organizations (NGOs)**. Since the informal recycling sector is often ill-equipped to organize for better working conditions, NGOs often play a key role in assisting them. NGOs assist the informal working sector in developing microenterprises and negotiating with local governments for employment and contracts. Women in Informal Employment: Globalizing and Organizing and The Global Alliance of Waste Pickers are two such organizations.
- **Identify entrepreneurs**. In some regions, the informal recycling sector is being incorporated into the formal waste management sector through innovative and entrepreneurial means (see, for example, Exhibit 11.5). Entrepreneurs are starting recycling businesses by developing user-friendly online portals and phone applications for on-demand recyclables pickup by informal sector workers. One such example is Kabadiwala, an online pickup service, which is currently in five areas of India.
- **Consider government employment**. Many cities in developing countries strive for comprehensive waste collection coverage. Some cities seek to achieve higher coverage by increasing their workforce, including integrating members of the informal recycling sector.

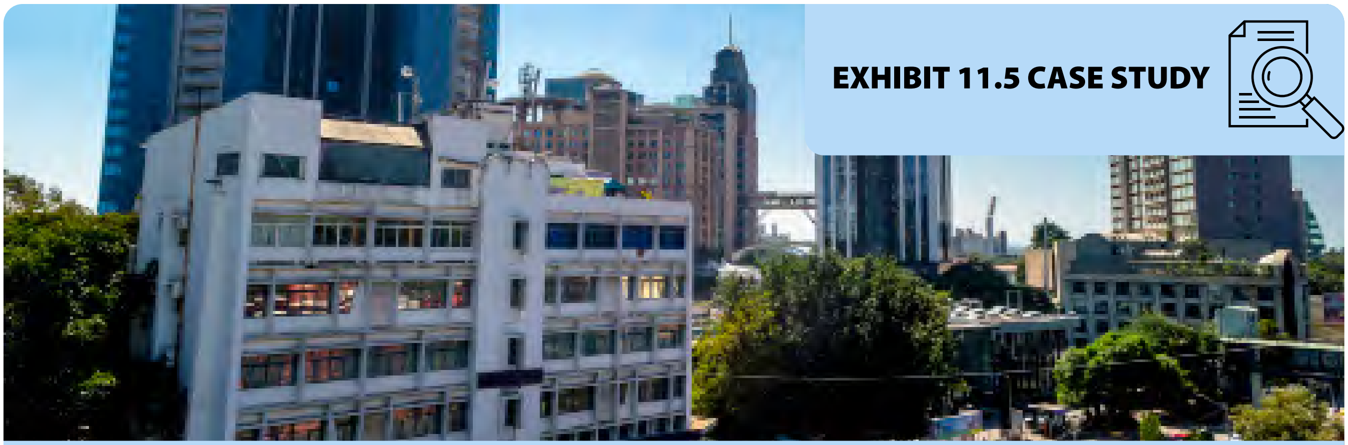


EXHIBIT 11.5 CASE STUDY

Incorporating Informal Sector Workers in Solid Waste Management Activities in Bangalore, India

In recent years the City of Bangalore has focused on micro-level planning for waste collection and treatment to reduce their costs and improve efficiency. Incorporating informal sector workers into the solid waste management system has been a key component of this effort. Currently, more than 15,000 informal sector workers handle waste in the city. These workers provide skilled labor that significantly reduces the city's solid waste management costs.

Since 2016 the city has formalized their relationship with the informal sector. The city provides informal sector workers with identification cards, offers certification courses, and has formed memoranda of understanding with groups of informal sector workers. One added benefit of working with the informal sector is that the city has reduced their dependence on traditional contractors, who sometimes overcharge for services and can be difficult to manage.

Groups of informal sector workers are typically based at transfer stations. Workers at some of these centers provide door-to-door collection, and then receive financial support from the city.

Informal sector workers in Bangalore have found innovative ways to integrate technological solutions into their work. Some have developed phone applications to monitor when their customers' waste bins have been emptied, how much waste was collected, and how well it is segregated (a requirement in India). This review allows informal sector workers to rate their customers' performance; higher ratings can lead to lower collection service fees.

To learn more about these activities, see Chengappa's (2013) ***case study on organizing the informal sector in Bengaluru*** ***and the*** ***Hasiru Dala website*** (Hasiru Dala 2015).

12 DUMPSITE MANAGEMENT

Key Resources

- Closing Dumpsites Knowledge Base (ISWA 2017a)
- Waste Atlas (Database of Global Waste Management Sites) (D-WASTE 2020)
- Improving Solid Waste Disposal in San Cristobal Municipality, Dominican Republic (U.S. EPA 2018c)
- Municipal Solid Waste Knowledge Platform [CCAC Undated(a)]
- A Roadmap for Closing Waste Dumpsites: The World's Most Polluted Places (ISWA 2016)
- Training Module: Closing an Open Dumpsite and Shifting from Open Dumping to Controlled Dumping and to Sanitary Land Filling (UNEP 2005b)
- Municipal Solid Waste Management in Developing Countries (Coursera 2019)
- Closure and Rehabilitation of Open Dumps (CCAC 2014)
- Waste Collection: A Report (Kogler, 2007)

Section 12

Dumpsite Management

Open dumpsites pose a significant risk to public health and the environment. Transitioning from open dumpsites to sanitary landfills (which are described in the Sanitary Landfills section) should be the ultimate goal for most cities and urban centers. However, that transition is typically complex and expensive, and requires extensive long-term planning. A phased transition that focuses on improving operations at existing dumpsites using low-cost techniques while developing sanitary landfills, and then eventually closing them and transitioning over to sanitary landfills, is a best practice in most situations.

This section describes several key benefits of managing open dumpsites and provides an overview of best practices for beginning the transition to sanitary landfills.

Why Focus on Open Dumpsites?

Without proper management measures, open dumpsites can cause a range of environmental and health impacts, including the following (see Exhibit 12.1):

- **Air pollution.** Open dumpsites emit methane, a precursor to ground-level ozone. Fires at open dumpsites release particulate matter and dioxins into the air. In addition to impacts on human health, these emissions also contribute to global and regional climate changes [for more information, see the *Climate and Clean Air Coalition Municipal Solid Waste Initiative's website* (CCAC Undated(e))].

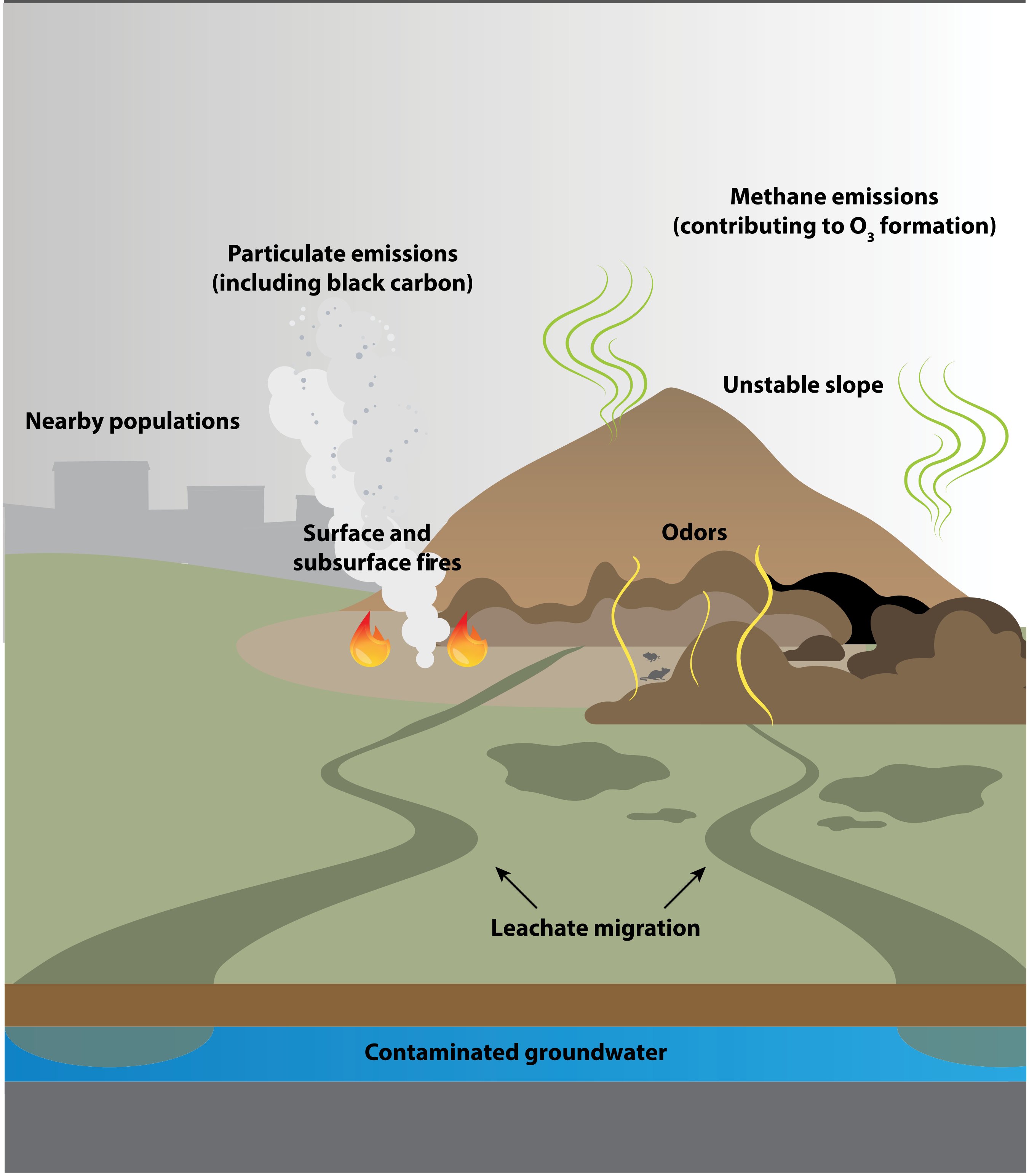
KEY POINT

Open Dumpsites, Controlled Dumpsites, and Sanitary Landfills

- An **open dumpsite** is an uncontrolled system that was not established with an engineering design.
- A **controlled dumpsite** is a disposal site that was not established with an engineering design, but where some management practices and infrastructure are in place (e.g., leachate collection and soil cover application).
- A **sanitary landfill** is differentiated from a dumpsite in that the landfill is an engineered design, consisting of a variety of systems for controlling the impacts of land disposal on human health, safety, and the environment.

For more information on the distinction between open dumpsites and landfills, see Table 2-1 in Global Methane Initiative's ***International Best Practices Guide for Landfill Gas Energy Projects*** (GMI 2012).

Exhibit 12.1. Impacts of Open Dumpsites on Health and the Environment



- **Risk of fires.** Open dumpsites have higher risks of spontaneous fires (both surface and subsurface) because more of the waste is exposed to oxygen. In some locations, informal recyclers burn waste to recover metals, which increases the likelihood of surface fires.

- **Groundwater and surface water contamination.** Rainwater that comes into contact with waste in open dumpsites quickly filters through waste and draws out chemicals that then leaches into soil and water resources.

- **Spreading disease.** Open dumpsites can attract insects, vermin, and other potential carriers of diseases that can infect workers and nearby populations.

- **Odors.** Foul odors from decomposing waste in open dumpsites can impact the aesthetics of areas near the site, diminishing property values and quality of life.

- **Slope failures.** Open dumpsites typically have unstable surfaces, which can result in slope failures; such failures can physically impact workers and nearby homes, and potentially result in fatal casualties.

Best Practices

This section describes best practices for beginning the transition to sanitary landfills, including improving operations at open dumps, converting open dumpsites to controlled dumpsites, and closing dumpsites.

Improving Operations at Open Dumps ✓

Simple upgrades can be made with little capital investment and minimal ongoing costs to reduce the environmental and health impacts of open dumps. Examples include:

- **Apply daily cover**. Applying daily cover material (e.g., dirt or compost) can reduce the immediate health and disease threats posed by exposed waste (GMI 2012).

- **Construct drainage**. Constructing drains around the perimeter of the dumpsite to catch runoff and leachate (USAID 2018).

- **Minimize leaching**. Compacting and grading soil periodically (every two months is often sufficient) helps minimize leaching through soil. This practice causes rainwater to run off into perimeter drains instead of soaking into the soil. Manual labor or heavy equipment may be used (renting heavy equipment is often the least-expensive option) (USAID 2018).

- **Implement practices that are protective of human health**. Protecting the health of informal sector and other workers by providing hygiene training, soap, and water. To minimize the risk of physical injury from sharp objects in dumps, workers should be provided with protective clothing, footwear, and equipment (USAID 2018).

- **Conduct regular monitoring**. Regularly testing groundwater for contaminants, including bacteria, heavy metals, and toxic organic chemicals (USAID 2018).

- **Cease disposal in unstable locations.** Continuing to dump waste in locations that are physically unstable can increase the risk of a slope failure. Cities can use excavators and other equipment to sculpt the working face of the site to make slopes more gradual so that they are more stable (U.S. EPA 2017a).

- **Install fencing**. Fences can help prevent waste from migrating offsite in windy conditions. Fencing can also help regulate who has access to the site, which can help reduce the risk of accidental fires and exposure to hazardous substances.

Converting Open Dumpsites to Controlled Dumpsites ✓

In addition to implementing initial low-cost improvements at open dumps, many cities have upgraded open dumpsites by converting them to controlled dumps. This alteration typically involves the following steps:

- **Conducting a site assessment.** A site assessment will help determine whether the location of the existing open dumpsite is suitable for conversion to a controlled dumpsite or for final closure. An alternative disposal site is needed if conversion is not practical (Coursera 2019).

CASE IN POINT

Closing Open Dumpsites in Oman

For more information, see ***be'ah's webpage on Oman*** (be'ah 2017a).

Until recently, Oman's waste was deposited into a diffuse patchwork of 317 open dumpsites and uncontrolled landfills, which posed environmental and public health hazards to those living near the dumpsites.

In 2009, the government issued a royal decree in support of revitalizing Oman's solid waste management infrastructure. In less than five years, the country's waste management authority successfully closed approximately 90 percent of the dumpsites in Oman, following a systematic process.

Dumpsite closures were prioritized using environmental and public health risk analysis criteria. Those dumpsites with the greatest potential for ongoing contamination, open burning, or safety concerns were pushed to the top of the closure list to minimize their adverse impacts. Prioritization also considered the closure timeline and associated costs.

- **Preparing the existing site.** Transforming an open dumpsite to a controlled dumpsite involves several steps, including leveling and compacting existing waste and constructing drainage canals/ditches, among other preparation activities (Coursera 2019). Operational procedures include limiting the working face area; covering exposed wastes with soil, sand, or clay; and installing a litter barrier (U.S. EPA 2002a). In rare cases when there is a minimal amount of waste in the dumpsite, the waste can be temporarily removed while a new liner and leachate collection system are installed [UNEP 2005(b)]. It is also a best practice for preparation activities to account for future onsite recycling by informal sector workers. Many cities have discontinued recycling activities at their dumpsites and instead have informal sector workers perform recycling activities at a more formal recycling effort offsite.
- **Monitoring the facility regularly** for waste volume and composition, methane gas production, surface water and groundwater conditions, and condition of drainage systems is a best practice (USAID 2018). Controlled dumpsites, if not monitored carefully, may still have problems that will need to be addressed, such as slope failures that occur as waste settles. Exhibit 12.2 presents a case study of a controlled dumpsite rehabilitation project in East Delhi, India.
- **Sealing and covering the dumpsite in stages** as its capacity to receive waste is exhausted (USAID 2018).
- **Maintaining scheduled monitoring** until sampling indicates it is no longer necessary – at least 10 years but possibly 30 years or more (USAID 2018).

Closing Dumpsites

Closing an open dumpsite does not simply mean abandoning it. Decomposition byproducts are produced long after closure; therefore, long-term planning and maintenance are necessary to minimize risks to cities post-closure (Coursera 2019). Best practices for closing open and controlled dumpsites include:

- **Conducting outreach.** Cities have found it helpful to identify the roles and responsibilities of those affected by the closure, such as the operator, residents, and other stakeholders. Engaging in discussions with these groups can help local authorities and decision-makers collect

KEY POINT

Closing Dumpsites Campaign

The International Solid Waste Association has established a campaign to close the world's 50 largest dumpsites. The *IISWA website* (ISWA 2017b) includes a range of resources to assist cities in planning dumpsite closure projects.

information on potential obstacles and gain buy-in. For example, it may be advisable to reach out to informal sector workers who depend on access to materials at open dumpsites for their livelihood; they can be formally included in plans to close the dumpsite and employed as workers at planned new facilities. For more information on stakeholder engagement strategies, see the *Stakeholder Engagement* section.

- **Developing a closure plan.** A closure plan details the activities that should occur during the closure of the site. Elements of the plan can include the stabilization of steep slopes to prevent erosion hazards, the implementation of leachate and gas management systems, and the design of the final cover. The plan should also consider measures to prevent future illegal dumping, unauthorized access at the closed site, relocation of informal settlers (if any), and the installation of monitoring wells (Coursera 2019).

  Capital expenditures for closure include the cost of final cover materials, drainage, leachate and gas management systems, and relocation of informal settlers, among others. Operational expenses generally include equipment and manpower requirements (Coursera 2019).

- **Developing a post-closure management plan.** A dumpsite will continue producing leachate and gas long after the site stops receiving waste. In addition, the site's final cover may erode over time due to precipitation and exposure to the elements. A well-designed post-closure plan allows for continued maintenance and monitoring of the site for at least 10 years (Coursera 2019).

- **Considering second uses of the closed dumpsite.** A properly closed dumpsite can later be used for another purpose, such as a recreational area or public green space, or for construction purposes. It is important to ensure that the risks of methane emissions and leachate contamination have been eliminated before public use of the space.

- **Being prepared for remediation and cleanup activities, as necessary.** Problems such as leachate leakage, waste slippage and exposure, fires, and explosions often result from improper or inadequate closure and post-closure procedures. Solutions may include excavation of soil or more aggressive cleanup technologies (Coursera 2019).

Questions for Decision-Makers

- What low-cost steps can the city take immediately to reduce the health and environmental impacts of an open dump?
- Should the dumpsite be closed or converted? If closed, is the site to be remediated?
- If a dumpsite is to be remediated, what guidelines should the city follow so as to minimize impacts on the environment and public health?
- What standards are achievable at the dumpsite?
- Should the city offer a waste transfer facility permanently or temporarily at a closed site?

EXHIBIT 12.2 CASE STUDY

Dumpsite Rehabilitation in East Delhi, India

The Ghazipur landfill in East Delhi opened in 1984. Beginning in the early 2000s, the site began to reach its maximum design capacity. However, due to the lack of a substitute disposal site, waste continued to be disposed of at the site.

On September 1, 2017, a portion of the landfill's slope failed. Waste from the landfill slid 110 meters across an area adjacent to the landfill, killing two people and injuring five more. This incident spurred a renewed urgency to improve operations and management at the landfill.

In response, the East Delhi Municipal Corporation worked with the Climate and Clean Air Coalition Municipal Solid Waste Initiative and the United States Environmental Protection Agency to conduct a detailed assessment of the landfill structure and operational practices that contributed to the slope's failure. The assessment provides recommendations for (1) reducing the risk of future slope failure, (2) mitigating the risk of landfill fires, and (3) estimating additional capacity at the landfill until an alternative is ready.

To learn more about these activities, see the United States Environmental Protection Agency's ***report on the Ghazipur landfill rehabilitation program*** (U.S. EPA 2017a).

13 SANITARY LANDFILLS

Key Resources

- Global Methane Initiative: Biogas Tools and Resources (GMI 2020)
- Municipal Solid Waste Knowledge Platform [CCAC Undated(a)]
- Sector Environmental Guideline Solid Waste (USAID 2018)
- International Guidelines for Landfill Evaluation (ISWA 2011)
- Landfill Operational Guidelines, 2nd Edition (ISWA 2010)
- Improving Solid Waste Disposal in San Cristobal Municipality, Dominican Republic (U.S. EPA 2017b)
- Sanitary Landfill Design and Siting Criteria (Cointreau 2004)
- International Best Practices Guide for Landfill Gas Energy Projects (GMI 2012)
- Waste Atlas (Database of Global Waste Management Sites) (D-WASTE 2020)
- Government of India Municipal Solid Waste Management Manual - Chapter 4.5: Municipal Sanitary Landfills (CPHEEO 2016)

Section 13

Sanitary Landfills

Sanitary landfills are designed to control and mitigate potential surface and groundwater contamination, reduce threats to sanitation workers, mitigate air pollutant emissions, and enable the collection of landfill gas (LFG) as a potential energy source.

This section provides basic information on the key features of sanitary landfills; and best practices for planning, siting, designing, and operating them.

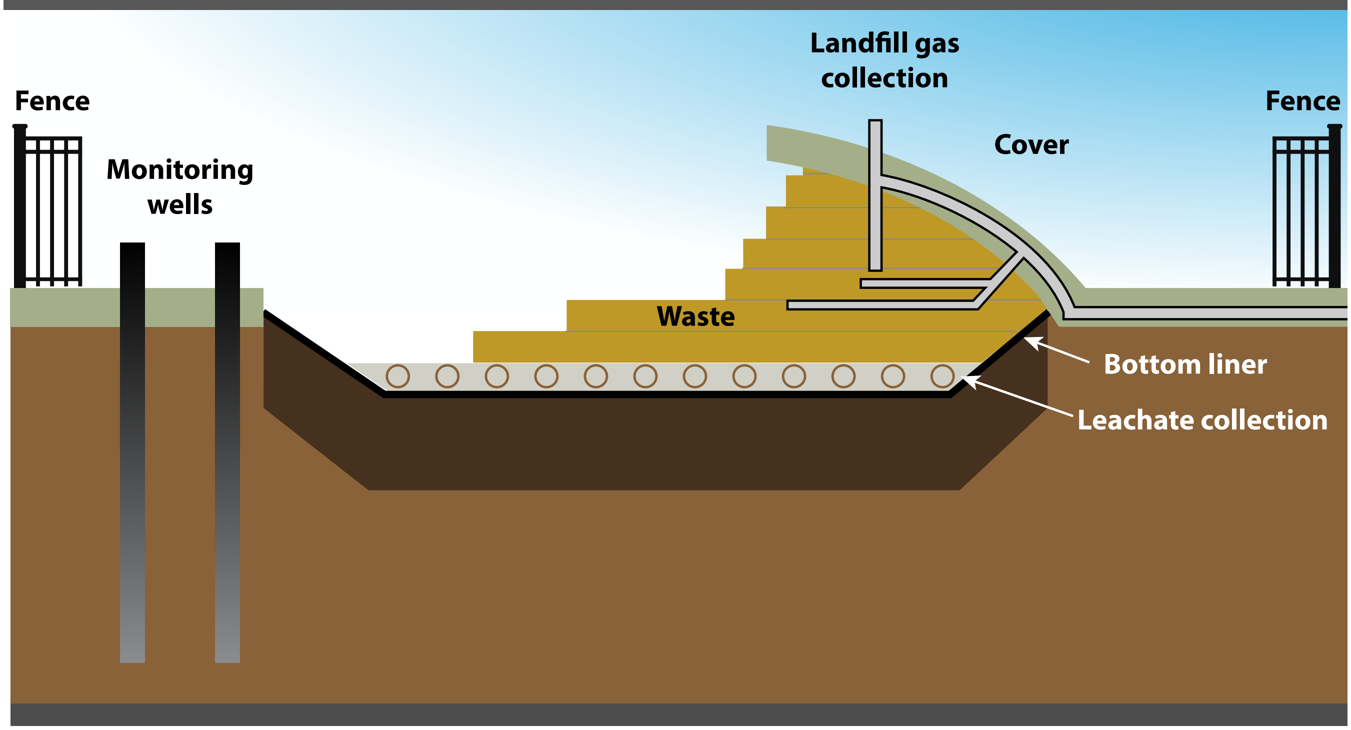
What Are Sanitary Landfills?

A modern sanitary landfill is a disposal site where all of the following practices are systematically implemented (Exhibit 13.1):

- Use of liners and leachate and gas collection systems to control or prevent adverse environmental impacts and their subsequent impact on public health and safety.
- Disposal of waste into a targeted and clearly defined working face.
- Compaction of the wastes to conserve land resources.
- Application of cover material on a daily basis to control the risk of hazards from exposed wastes.
- Design and operation of the landfill to control for and minimize human settlement in and close to the landfill.
- Groundwater monitoring to detect any potential leaks in the liners.

A well-established approach in the long-term is to implement all these practices in a systematic manner. However, implementing all of these practices may be technologically and economically challenging in some developing countries. Therefore, the short-term

Exhibit 13.1. Cross-Section of a Typical, Properly Designed, Constructed, and Maintained Sanitary Landfill



KEY POINT

Handling Special Wastes

Some low-density materials (e.g., plastic film and foam) require skillful handling and processing at the landfill to achieve proper compaction and minimize litter. Hazardous waste may require special handling due to its toxicity, corrosivity, or other dangerous property (Savage et al. 1998). For more information on handling special wastes, see the ***Waste Characterization section***.

goal is to implement as many of them to the greatest extent possible under existing circumstances. The most important goal is the prevention of negative impacts on public health and the environment (Savage et al. 1998).

Best Practices

This section highlights best practices for all aspects of sanitary landfilling, including how to consider waste composition, landfill costs, siting, design, operating and managing the site, and closure and post-closure.

Waste Composition

The composition (type and quantity) of solid waste buried in the landfill is an important determinant of the types, quantities, and characteristics of the byproducts emitted to the air and ground. These emissions occur as a consequence of the processes occurring within the landfill. Designing sanitary landfills to handle the quantity and types of waste intended to be disposed of at the site is a well-established approach (Savage et al. 1998).

Cities have found it important to consider the following waste-related variables when planning sanitary landfills:

- Whether a city has **quality data** on the quantity and composition of the waste to be disposed of in the landfill, which is distinct from the overall composition of the waste generated by the population the city serves. During the planning process, the city determines the rate of solid waste flow into the disposal site, and identifies and evaluates all factors that influence the flow-over time (current and future rates) because the landfill will operate for several years. The *Waste Characterization* section discusses best practices for waste stream characterization in greater detail.
- Current and potential future waste **diversion programs** (e.g., for organic waste or recyclables), and their impacts on waste quantities and types disposed of at the site.
- Whether the waste stream is likely to include **hazardous wastes** or wastes that pose specific risks when disposed of that should be treated separately (e.g., medical wastes). These wastes should be considered "unacceptable" at a sanitary landfill.

Landfill Costs

It is important to understand from the onset the costs of designing, building, operating, and monitoring a sanitary landfill during its operational, closure, and post-closure life stages. Without a clear understanding of these costs and how they will be paid, cities face the risk of having to cancel the landfill project before it is complete (e.g., due to insufficient financing) or close the landfill after it is built (e.g., if operations prove too costly). Cities also need to reserve sufficient funding to cover the costs of maintaining and monitoring a landfill after it has been closed; inadequate post-closure maintenance

KEY POINT

Factors to Consider When Determining Landfill Costs

- Characteristics and quantities of waste to be disposed of
- In-place density of waste and the ratio of cover material to solid waste
- Availability of suitable soil for use as a cover and liner materials
- Purchasing and preparing the site, which could include relocation of people and businesses
- Ruggedness of the terrain and ease of access to the site
- Phased landfill construction
- Regulatory requirements
- LFG collection and utilization infrastructure requirements
- Leachate treatment system requirements
- Post-closure maintenance and monitoring plans

can result in the site failing to contain the waste and associated byproducts.

Challenges of Estimating Landfill Costs

The scarcity of reliable data on landfill costs is a major challenge in many cities. Thus, conducting an organized data collection effort is an important first step in accurate cost estimation. In brief, this process involves recording all applicable costs (e.g., cost elements such as site preparation), estimating the magnitude of the cost for each element, and calculating the total cost at scale. Section 18.8 in the Guidance for Landfilling Waste in Developing Countries (Savage et al. 1998) includes worksheets on estimating annual costs. Although the models use historical United States Environmental Protection Agency data from the United States, the cost estimation method is useful for general planning.

One method of estimating landfill costs is to examine past and current landfill operations in another jurisdiction near the proposed disposal area, and to obtain or estimate the costs. It is important to take both capital and operational costs into account.

Use of Diversion Programs

In some instances, leveraging waste diversion programs can help mitigate the costs of building and operating a landfill. For example, many cities have used waste diversion programs to reduce the volume of waste that needs to be disposed of, thus allowing them to build a smaller landfill at lower costs or build a landfill that will last longer. In general, higher costs for landfilling can make diversion programs more cost-effective. For example, recycling programs that might be otherwise be too expensive to implement might become more economical if the costs of landfilling are high. For more information on the management of waste before it reaches the landfill, see the *Organic Waste Management* and *Recycling* sections.

Options for Cost Recovery

Cities can recover the cost of operating a landfill by collecting "tipping fees." Tipping fees are generally charged according to the weight or volume of the waste and the type of waste. More information on cost estimates and recovery options can be found in the *Economic Considerations* section.

Cities can also use LFG recovery and utilization projects to offset the cost of landfill operations. In these projects, LFG is collected and used to generate electricity for direct combustion (e.g., in a boiler on-

Exhibit 13.2. Ideal Geologic Characteristics for Siting a Landfill

Geological stability. Areas prone to geological hazards, such as active seismic zones, fault zones, floods, and avalanches, are avoided.
Impermeable layer at the base of the landfill. Permeability describes the rate at which water passes through soil or another substrate (e.g., locating the landfill in an area with clay soils – through which water cannot flow – will provide ideal protection).
Distance from surface waterbodies. Locating the landfill far from surface waterbodies (e.g., more than 1,000 meters) minimizes the potential for flooding at the landfill and contamination of the waterbodies.
Low hydraulic conductivity in the first aquifer located under the landfill to minimize the potential for contaminants to move to a different aquifer.
Nearest aquifer under the base of the landfill is deep and not used for drinking purposes.
Unsaturated layer below the landfill base contains both air and water between the soil and rocks (e.g., more than 30 meters).

or offsite) or for other uses (e.g., transport fuel). These uses of LFG reduce the need for cities to purchase other sources of energy. For more information on best practices for LFG energy projects, see the Global Methane Initiative's (GMI's) International Best Practices Guide for Landfill Gas Energy Projects (GMI 2012). The initiative has also developed several cost-free, Excel-based tools for modeling LFG (GMI Undated(d)) in specific developing countries.

Site Selection

Several factors are important to consider when selecting a site for a landfill, including geological and non-geological factors.

Geological and hydrological elements

Geologic and hydrologic information can be used to select areas that are more favorable to landfill development, and to assist in designing the landfill to minimize the potential for environmental contamination. Exhibit 13.2 presents ideal geologic and hydrologic characteristics for siting a landfill.

Non-geological considerations

Demographic and political considerations. Cities should consider demographic and political factors, such as boundaries, property ownership and use rights, potential reactions from the local population, and potential impacts to marginalized populations.

Potential landfill capacity. Sanitary landfills are typically designed to accommodate many years of waste disposal. Cities typically calculate the desired volume (or capacity) of the landfill based on the amount of waste generated per person per year, population size, anticipated population and economic growth, alternative waste treatment processes, and the number of years the landfill is intended to be in operation (U.S. EPA 2002a). More information on estimating future waste can be found in the *Waste Characterization* section.

Transportation distances. The farther a landfill site is from the point where the waste is generated and collected, the higher the costs of waste transport. If the landfill is remote from the collection area, cities have found transfer stations helpful for consolidating waste from collection vehicles into a bulk transport system. More information on transfer stations and planning a route can be found in the *Separation, Collection, and Transportation* section.

Questions for Decision-Makers

- What geographic area should the site serve and for how long?
- What site selection criteria will be used?
- What are the views of residents and organizations with an interest in the site location?
- How will these views be accounted for in the decision-making process?

CASE IN POINT

Generating Electricity from LFG in Sao Paulo, Brazil

São Paulo, Brazil, generates approximately 15,000 metric tonnes of solid waste each day. Much of this waste was disposed of at the city's São João Landfill from 1992 to 2008. At the time of its closure, the facility had approximately 24 megagrams of waste in place and a footprint of 70 hectares.

In 2006, São Paulo began plans to construct a LFG energy project to capture and use the large quantities of LFG generated in the landfill. The project was completed in 2008. The plant combusts LFG in 16 engines, each with a 1.54-megawatt capacity, and has a total electricity production capacity of 22.4 megawatts. Three flares are used to combust LFG that is not used to generate electricity.

To learn more about these activities, see the detailed case study in the GMI ***International Best Practices Guide for Landfill Gas Energy Projects*** (GMI 2012).

Site Preparation

Physically preparing the terrain for the construction of a sanitary landfill may involve the following activities (Savage et al. 1998):

- **Clearing and grubbing.** It is best to remove trees, brush, plants, rocks, and other matter that may impede the operation of equipment or hinder the performance of the landfill, including any root systems that might impact the long-term durability of the liner system.
- **Preparing for drainage, erosion and sedimentation control, and site access.** Cities typically construct roads, ditches, and other physical features to enable drainage, erosion and sedimentation control, and site access. These features are needed for the duration of site preparation activities and potentially as part of the permanent landfill design.
- **Excavating earth and stockpiling.** The majority of landfill sites require substantial excavation of earth materials in preparation for the landfill. The excavated materials can be used in subsequent operations (i.e., as a cover material).
- **Creating buffers.** Buffers are areas of land outside the boundary of the solid waste. Creating a sizeable buffer zone improves public acceptance of the landfill and its operation.

Landfill Design

Above all, it is a best practice to design landfills to protect human health and the environment. Specific design criteria account for national or regional requirements, but there are several common design features:

- **Bottom liner.** Liners are used to prevent leachate from entering groundwater by keeping fluids within the landfill area. Liners are made of relatively impermeable material such as compacted soil or clay, synthetic materials, or a composite of earthen and synthetic materials. Well-compacted clay soil is most commonly used because of its impermeable properties and general availability (Savage et al. 1998).
- **Leachate collection and treatment.** In a properly lined landfill, leachate accumulates within the landfill. Keeping the amount of leachate within the landfill to a minimum is

KEY POINT

Key Steps in Collecting and Treating Leachate

1. Identifying and selecting the type of liner to be used (e.g., impermeable soil or clay layer)
2. Preparing a grading plan for the site, including location of channels and pipeline for the collection and removal of the leachate
3. Designing the facilities for the removal, collection, and storage of the leachate
4. Selecting and designing the leachate treatment system (Savage et al. 1998).

important because water pressure can push leachate through a permeable liner or through imperfections in the liner. Therefore, well-designed landfills include equipment to collect and divert the leachate from the landfill and treat it. Perforated piping, for example, can be installed to collect the leachate and divert it for treatment. Treatment alternatives include (1) discharge to a wastewater treatment system, (2) evaporation of leachate stored in an evaporation pond, (3) recirculation or recycling of leachate through the landfill environment (which can increase LFG generation and collection rates), and (4) onsite treatment (Savage et al. 1998, U.S. EPA 2002a).

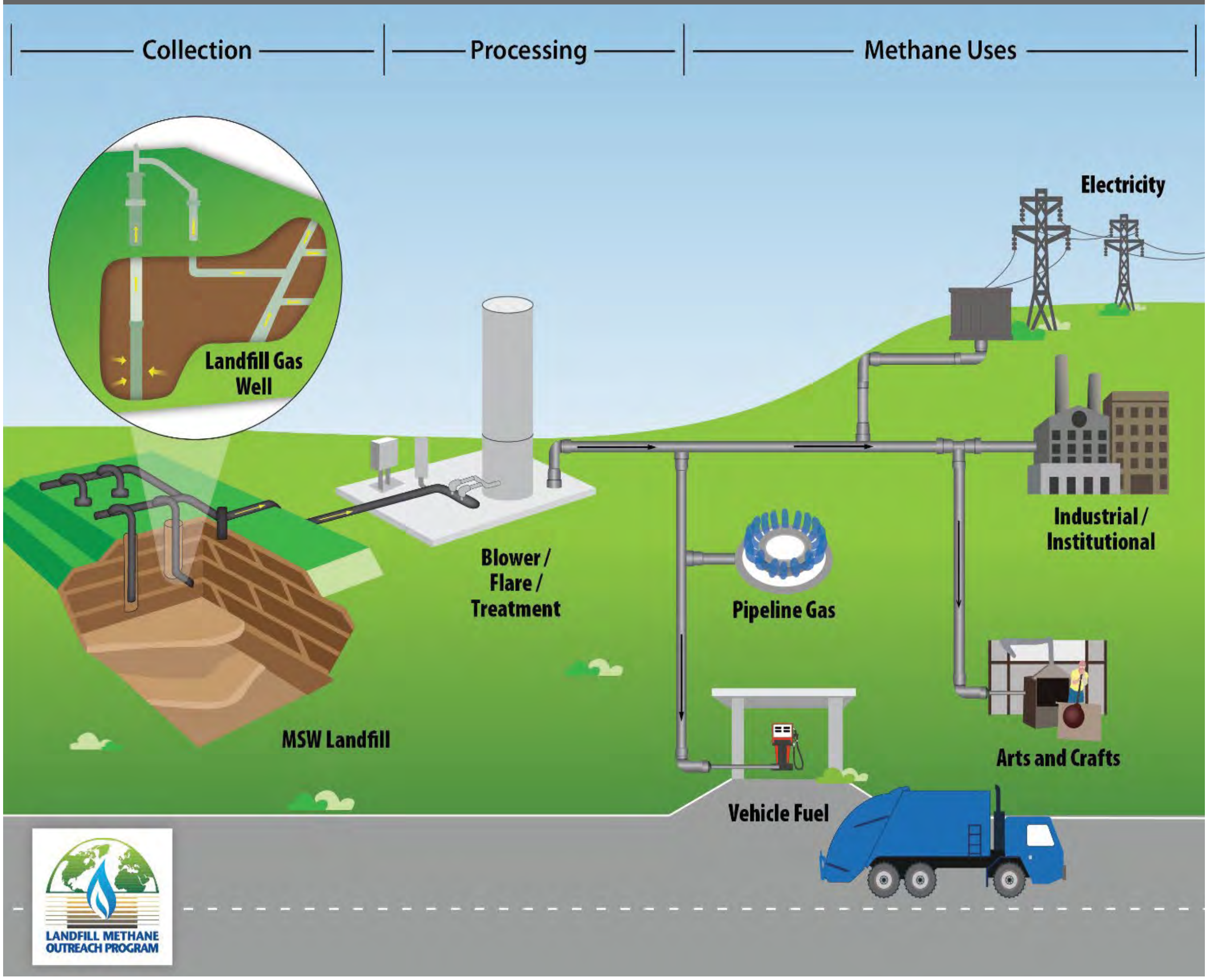
- **Cover.** A typical sanitary landfill has two forms of cover: (1) a daily cover placed over the waste on the working face at the close of each day's operations; and (2) a final cover, or cap, which is the material placed over the completed landfill. The cover typically includes natural and synthetic materials such as dirt, compost, shredded tires, and geosynthetic membranes.
- **LFG collection and energy recovery**. LFG collection and energy recovery are important aspects of sanitary landfill operations. LFG is generated as a byproduct of decomposition of certain types of waste.

As illustrated in Exhibit 13.3, LFG collection systems can help collect, move, and flare or productively use this gas. Flaring the gas helps reduce the risk of spontaneous fires and mitigates methane emissions. LFG energy projects can be designed to harness collected gas to generate electricity or for other productive uses. The *GMI International Best Practices Guide for Landfill Gas Energy Projects* (GMI 2012) includes additional information on how to implement an LFG

Questions for Decision-Makers

- Does the city's solid waste management department have the skills to design the site? If not, can these skills be obtained from other parts of the city or from the private sector
- What standards will the city follow?
- How will informal sector workers be impacted, and how will the city mitigate these impacts?
- How will the facility collect and use LFG? Are there nearby facilities that would use captured LFG?

Exhibit 13.3. Illustration of the Collection and Processing of LFG to Produce Methane for Multiple Uses (U.S. EPA 2019c)



energy project. The Climate and Clean Air Coalition Municipal Solid Waste Initiative offers a LFG Project Screening Tool (CCAC Undated(b)) to help cities evaluate the feasibility of a potential LFG energy project.

- **Groundwater monitoring**. Monitoring is necessary to determine groundwater quality at a facility and to determine whether there has been a release of contaminants through the base of the landfill. The groundwater monitoring system consists of wells placed at an appropriate location and depth for taking water samples that are representative of groundwater quality (U.S. EPA 1995).
- **Site access**. Building a fence around the site can strictly control access to the landfill and prevent injury, unauthorized waste picking, and illegal dumping (U.S. EPA 2002a). It is important to consider how restricting access to the site might impact the livelihoods of individuals who make a living recovering and selling recyclable materials. Many cities are mitigating these impacts by integrating informal sector workers into formal collection or disposal operations (e.g., helping them organize a cooperative and offering them structured access at the landfill gates).

Landfill Operation

Many cities have found it helpful to hire a trained landfill manager to properly operate and manage the site. Before any waste is disposed of at the landfill, the manager develops a plan to serve as the operational guide for the site. The plan typically specifies, in detail, the site location where waste is to be placed, how the site will be operated, how often and where a soil cover will be used, and how environmental problems (e.g., animals, litter, fires, gas, leachate) will be addressed. Other key operational considerations include waste compaction, application of daily cover, leachate treatment and monitoring of leachate and water quality, management and monitoring of landfill emissions and gas, and application of the final cover (Munawar and Fellner 2013).

Closure and Post-Closure Operations

When a landfill reaches maximum capacity, filling operations cease, and the site is "capped" with a final cover system. The period of time during which the landfill is subsequently maintained and monitored is referred to as the "post-closure period." The activities listed below are broadly categorized into closure and post-closure phases.

Closure of the landfill involves the following activities:

- Cessation of waste delivery for disposal by burial at the landfill
- Preparation of the site to receive the final cover system or cap
- Installation of the final cover system
- Re-examination of the leachate management system to assess performance
- Provisions for gas collection and control
- Improvements or repairs to drainage systems, erosion control features, access roads, etc.
- Restoration of disturbed peripheral areas
- Legal restrictions to prohibit the reuse of the closed landfill area for certain types of activities.

Post-closure activities at the landfill include cover system maintenance, leachate management, gas management, erosion and sedimentation control, surface water management, and site access and security. In addition, post-closure activities should also include environmental monitoring and special provisions for future use of the site.

Closure and post-closure care are important activities in the lifecycle of a landfill because they complete the requirements for environmental management of the facility. Generally, post-closure care should continue until the solid waste has stabilized to a level at which it is no longer hazardous to public health and safety or to environmental quality. This stabilization process can last several decades.

The study cited in the case study below (Exhibit 13.4) is a valuable resource for understanding best practices associated with converting a dumpsite to a sanitary landfill.

Questions for Decision-Makers

- Are there enough skilled personnel to operate the new landfill site? What training would they need, and where will that training come from?
- Should the city contract out the operation to the private sector?
- Is there enough money allocated for operations for it to be done properly?
- Are there additional revenue sources that can help offset operations costs (e.g., tipping fees)?

EXHIBIT 13.4 CASE STUDY

Developing a Roadmap for Transitioning to a Sanitary Engineered Landfill in San Cristobal, Dominican Republic

San Cristobal is a city of approximately 250,000 inhabitants located 30 kilometers from Santo Domingo in the Dominican Republic. Since 2014, the city's primary disposal site has been a semi-controlled dumpsite that receives between 210 and 270 metric tonnes of waste daily. Access to the site is not controlled, resulting in unsafe scavenging and harmful fires. In addition, the site does not have a liner system, groundwater monitoring, or a soil cover. Because of the unsafe conditions at the site, and the associated impacts on health and aesthetics, the city has received many complaints from its residents.

In response, the municipality has begun working with the Ministry of Environment and Natural Resources, the United States Agency for International Development, and the United States Environmental Protection Agency to develop a plan for improving and ultimately closing the current dumpsite, and transitioning to a sanitary engineered landfill.

Between 2017 and 2018, the city and its partners conducted multiple field assessments to collect data on current solid waste management practices and meet with stakeholders. Based on this information collection effort, the city's partners prepared recommendations for improving current site operations (e.g., by establishing a proper working face), converting the site to an engineered landfill (e.g., by designing leachate treatment and LFG collection systems), and contracting with the private sector. The recommendations were presented to stakeholders in August 2018.

The final recommendations are in the rport ***Improving Solid Waste Disposal in San Cristobal Municipality, Dominican Republic*** (U.S. EPA 2018c).

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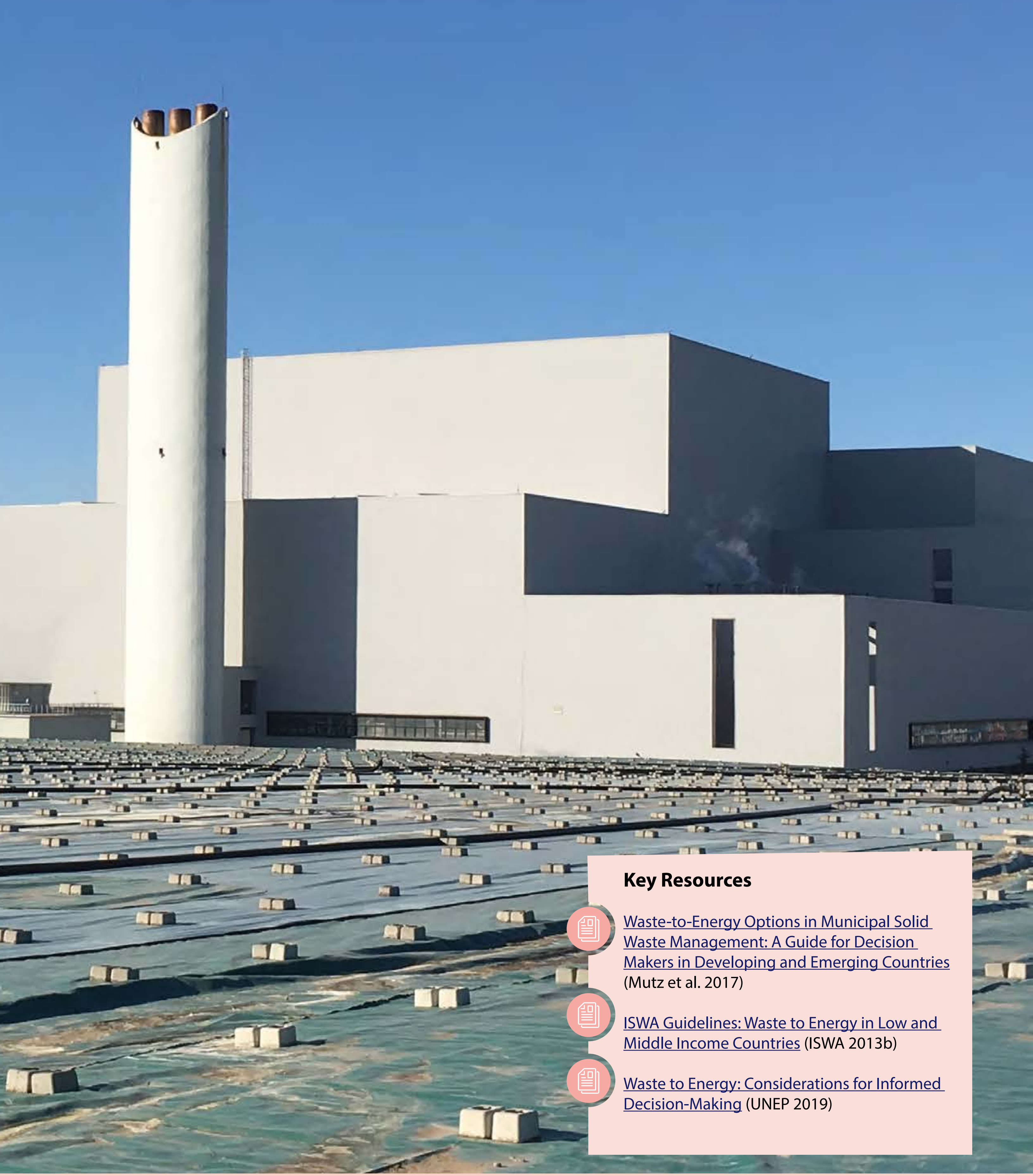
14 ENERGY RECOVERY



Key Resources

- Waste-to-Energy Options in Municipal Solid Waste Management: A Guide for Decision Makers in Developing and Emerging Countries (Mutz et al. 2017)
- ISWA Guidelines: Waste to Energy in Low and Middle Income Countries (ISWA 2013b)
- Waste to Energy: Considerations for Informed Decision-Making (UNEP 2019)

Section 14

Energy Recovery

Approximately 15 percent of all waste that is treated globally is incinerated with energy recovery (UNEP 2019). The majority of energy recovery facilities are currently located in developed countries, but many developing countries are interested in this solid waste management strategy because of the potential to eliminate large quantities of waste that is otherwise not recyclable. In addition, these facilities can generate an alternative energy source and preserve landfill space. Nevertheless, there are many challenges associated with developing and successfully operating an energy recovery project, and cities are encouraged to carefully consider if energy recovery is the right option for their specific situation and needs.

This section focuses on energy recovery processes that involve converting non-recyclable material into usable heat, electricity, or fuel. In particular, it discusses different energy recovery technologies, and important factors to consider when determining whether to include energy recovery as a part of a solid waste management system. This section does not address biogas projects that produce energy from anaerobic digestion (AD) of organic waste, or landfill gas (LFG) projects. These topics are addressed in the Organic Waste Management and Sanitary Landfills sections, respectively.

Why Consider Energy Recovery?

Energy recovery projects can help eliminate waste materials that are otherwise not recyclable, while providing a source of energy that can be used in a variety of applications, including district heating and cooling. In addition, energy recovery projects can help reduce the volume of waste sent to disposal sites, a particularly appealing advantage in locations that have limited dumpsite or landfill capacity.

Waste-to-energy (WtE) projects (or "waste from energy") can also improve public health and safety by removing waste from open dumpsites (UNEP 2019). That said, having regulatory and environmental frameworks (e.g., emissions control technologies) in place to ensure that WtE projects do not exacerbate local air quality concerns is critical for the success of the projects in achieving environmental and health objectives.

Types of Energy Recovery

Energy recovery, or WtE, is the process of converting non-recyclable material into usable heat, electricity, or fuel. This conversion can be accomplished through a variety of processes, including (Mutz et al. 2017):

- **Combustion.** Combustion or incineration is the burning of solid waste in specialized facilities to create heat, steam, or electricity. Combustion requires carefully managing exhaust emissions (e.g., particulates and gases) and safely disposing or beneficially using solid ashes in order to reduce the environmental impacts of the process. Combustion ash is typically landfilled (U.S. EPA 2016d).

- **Co-processing.** Co-processing uses waste as a substitute for fossil fuels in industrial processes, such as cement manufacturing. Refuse-derived fuel is required for co-processing in order to ensure controlled combustion. Refuse-derived fuel is generally made up of relatively homogenous waste and is achieved through a series of pre-processing steps, which requires additional capital. Co-processing helps to reduce carbon dioxide emissions by using biomass fuels and mixed fuels, and can also be a viable treatment option for non-recyclable plastics (Hinkel and Blume 2018).

CASE IN POINT

Public Private Partnerships in China

For more information, see ***Sustainable Urban Development in the People's Republic of China: Municipal Solid Waste Treatment: Case Study of Public-Private Partnerships (PPPs) in Wenzhou*** (ADB 2010).

The City of Wenzhou, China, was facing increasingly more household waste each year. Historically, household waste in the area went to two landfills. In 2002, the city partnered with a local private contractor to build and operate an incineration plant for two years. At the end of two years, the government would own and operate the plant without any compensation to the private investor. The large plant is able to sell 7 million kilowatts of electricity per year. The plant also receives a service fee from the Wenzhou city government for the disposal of solid waste.

Challenges

WtE can be a solution to reduce waste and provide an alternative energy supply. However, there have been few successful WtE projects in developing countries; challenges that cities face for each type of energy recovery technology include (Mutz et al. 2017):

- **Substantial capital investment to build and operate facilities.** Operational costs include fixed operating costs (e.g., salaries) and variable operating costs (e.g., maintenance, utility usage, emissions systems). While WtE facilities can be made economically viable with tipping fees, sales from electricity, and sales from other co-products (e.g., recovered metals), it can take years for a facility to become profitable. Often, the revenue from energy production does not cover the operational costs of the facility, so cities must be able and willing to look for additional types of financing, such as public-private partnerships (PPPs). In addition, electricity prices can fluctuate, meaning energy recovery from solid waste may not be the most competitive option.
- **Emissions and solid waste management.** WtE facilities generate waste products that need to be appropriately handled and disposed of, including bottom and fly ash. Some of these waste products can be mitigated by using control and monitoring technologies for air and water emissions, conducting proper containment and disposal of ash and other waste, controlling noise from machinery and transport vehicles, and properly handling and storing hazardous wastes. It is important that cities have adequate air monitoring and compliance mechanisms to ensure that WtE facilities meet regulatory and emission standards.
- **Specific feedstock requirements.** WtE requires feedstocks with specific calorific-content thresholds that may not be achievable for cities or urban centers that do not separate waste streams. Mixed waste can have too much moisture content or too little caloric value, and some countries' regulations prohibit burning of low-calorie wastes. In addition, climactic conditions can make proper feedstock difficult to obtain. For example,

in the Caribbean, high wet organic waste content and harsh environments lead to the rapid corrosion of energy-recovery equipment (IDB 2016). In many cities, WtE projects may compete with recycling efforts for recyclable materials with high-calorific values.

- **Education and training of staff.** Knowledgeable and skilled staff are required to implement and operate the facility. Cities have found it beneficial to ensure that facilities hire qualified staff, and that all staff receive training.

- **Conflicting, long-term commitments.** Constructing and operating WtE facilities requires a long-term commitment from the city. These commitments can conflict with other local priorities, such as greenhouse gas emissions reductions and overall waste generation reduction targets (since reduced waste generation rates mean less feedstock for the facility)

AD digestion and LFG recovery are two other ways to recover energy from waste. The *Organic Waste Management* and *Sanitary Landfills* sections provide more information on AD and LFG recovery, respectively.

When to Consider WtE

Energy recovery can be an integral part of a functioning solid waste management system. However, according to the solid waste management hierarchy described in the *Approaches* section, it is a best practice to implement both source reduction and recycling strategies before considering energy recovery as an option (U.S. EPA 2019a), or implement all three strategies in tandem. Additionally, because of the potential risks associated with energy-recovery technologies (especially those that do not incorporate emissions control equipment), these projects are a viable option only in cities with functioning and efficient solid waste management systems, and environmental management protocols in place.

Questions for Decision-Makers

- Is an efficient solid waste management system already in place?
- What environmental legislation is in place to protect against pollution caused by WtE? Are all technologies covered by legislation? Are monitoring mechanisms in place?
- How can the city ensure high-quality streams of waste suitable for combustion?
- How will the city train staff to ensure they have the skills to operate the facility?
- Have end users for the electricity or heat been identified and approached?
- Have all project costs been considered and alternative methods of finance been identified? Is there security for the investors?

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Bibliography

ABRELPE. 2020. Lixo Fora D'Agua. Brazilian Association of Public Cleansing and Waste Management Companies. http://lixoforadagua.com.br/. Accessed May 1, 2020.

ABRELPE. Undated. Santos: Setting the Scene of the Local Waste Management System. Brazilian Association of Public Cleansing and Waste Management Companies. http://lixoforadagua.com.br/wp-content/uploads/RELATO%CC%81RIO%202-%20ENG%20Santos.pdf. Accessed May 19, 2020.

ABRELPE and CCAC. 2017. Handbook on Communication and Engagement for Solid Waste Management. Brazilian Association of Public Cleansing and Waste Management Companies and Climate and Clean Air Coalition. https://www.waste.ccacoalition.org/document/communication-and-engagement-solid-waste-management-handbook. Accessed November 7, 2019.

Abt Associates, SCS Engineers, U.S. EPA, and CCAC. 2017. Landfill Gas Project Screening Tool. Version 2. June. Abt Associates, SCS Engineers, United States Environmental Protection Agency, and Climate and Clean Air Initiative. https://www.waste.ccacoalition.org/document/landfill-gas-project-screening-tool-version-2. Accessed November 7, 2019.

ADB. 2010. Sustainable Urban Development in the People's Repulic of China: Municipal Solid Waste Treatment: Case Study of Public-Private Partnerships (PPPs) in Wenzhou. Asian Development Bank. https://www.adb.org/sites/default/files/publication/27864/urbandev-prc-nov2010-waste.pdf. Accessed January 30, 2020.

ADB. 2013. Materials Recovery Facility Toolkit. Asian Development Bank. https://www.adb.org/sites/default/files/publication/30220/materials-recovery-facility-tool-kit.pdf. Accessed April 27, 2020.

ADB and the Australian Government Aid Program. 2011. Toward Sustainable Municipal Organic Waste Management in South Asia. A Guidebook for Policy Makers and Practitioners. Asian Development Bank and the Australian Government Aid Program. Mandaluyong City. https://www.adb.org/publications/toward-sustainable-municipal-organic-waste-management-south-asia. Accessed November 7, 2019.

Akenji, L. 2012. Applying EPR in Developing Countries. IGES Rio +20 Issue Brief Vol.3. https://iges.or.jp/en/publication_documents/pub/issue/en/2561/rio_issue_brief_vol3_EPR_mar2012.pdf. Accessed January 30, 2020.

Allen, C. 2012. La Pintana, Chile: Prioritizing the Recovery of Vegetable Waste. Case Study, Global Alliance for Incinerator Alternatives. Global Alliance for Incinerator Alternatives. https://www.no-burn.org/wp-content/uploads/ZW-La-Pintana.pdf. Accessed November 7, 2019.

Aluminum Association. 2019. Aluminum Recycling. Economically & Environmentally Sustainable. The Aluminum Association. https://aluminum.org/advocacy/top-issues/aluminum-recycling. Accessed November 7, 2019.

Aparcana. 2017. Approaches to formalization of the informal waste sector into municipal solid waste management systems in low- and middle-income countries: Review of barriers and success factors. Waste Management 61. 10.1016/j.wasman.2016.12.028.

Basel Convention. 2020. Plastic Waste Overview. http://www.basel.int/Implementation/Plasticwastes/Overview/tabid/6068/Default.aspx. Accessed May 1, 2020.

BBC News. 2002. Bangladesh Bans Polythene. BBC News. January 1. http://news.bbc.co.uk/2/hi/south_asia/1737593.stm. Accessed November 7, 2019.

be'ah. 2017a. Electronic Services. https://beah.om/. Accessed October 28, 2019.

be'ah. 2017b. Sustainability. https://www.beah.om/Other/Sustainability. Accessed May 19, 2020.

Brazilian NR. 2010. Law No. 12305 – Brazilian Policy on Solid Waste. Brasilia: Ministry of the Environment in Brazil. August 2. http://www.braziliannr.com/brazilian-environmental-legislation/law-no-12305-brazilian-national-policy-solid-waste/. Accessed November 7, 2019.

C40 Cities. 2016a. C40 Good Practice Guides: Dhaka – Composting Project. February 15. https://www.c40.org/case_studies/c40-good-practice-guides-dhaka-composting-project. Accessed November 7, 2019.

C40 Cities. 2016b. Good Practice Guide: Sustainable Solid Waste Systems. http://c40-production-images.s3.amazonaws.com/good_practice_briefings/images/9_C40_GPG_SSWS.original.pdf?1456789082. Accessed November 7, 2019.

C40 Cities. 2017. Explainer: How to Finance Urban Infrastructure? https://www.c40cff.org/knowledge-library/explainer-how-to-finance-urban-infrastructure. Accessed January 28, 2020.

C40 Cities. 2018. Case Study: Electric Urban Cleaning Vehicles to Drive Down City's GHG Emissions, Save Costs, and Improve Citizens' Health. December 3. https://www.c40.com/case_studies/electric-urban-cleaning-vehicles-to-drive-down-city-s-ghg-emissions-save-costs-and-improve-citizens-health. Accessed November 7, 2019.

Cascadia Consulting Group. 2003. Guidelines for Waste Characterization Studies in the State of Washington. Washington State Department of Ecology. Publication No. 15-07-040. https://fortress.wa.gov/ecy/publications/documents/1507040.pdf. Accessed November 7, 2019.

Cascadia Consulting Group. 2012. City of San Diego Waste Characterization Study: Study Design. November 2. https://www.waste.ccacoalition.org/document/waste-characterisation-study-san-diego. Accessed November 7, 2019.

Cascadia Consulting Group. 2018. 2015–2016 Washington Statewide Waste Characterization Study. State of Washington Department of Ecology. Publication 16-07-032. Published October 16 – Updated January 2018. https://fortress.wa.gov/ecy/publications/documents/1607032.pdf. Accessed November 7, 2019.

CCAC. 2014. Closure and Rehabilitation of Open Dumps. Webinar, November 13. Climate and Clean Air Coalition Municipal Solid Waste Initiative. https://www.waste.ccacoalition.org/seminar/closure-and-rehabilitation-open-dumps. Accessed February 4, 2020.

CCAC. 2015. Workplan for Addis Ababa. Climate and Clean Air Coalition. https://www.waste.ccacoalition.org/sites/default/files/files/ccac_workplan_addis_final_2-25-2015.pdf. Accessed February 3, 2020.

CCAC. 2018a. Anaerobic Digestion Project Screening Tool (AD_PST). Version 1. July. Developed by Abt Associates for the United States Environmental Protection Agency and Climate and Clean Air Coalition Municipal Solid Waste Initiative. https://www.waste.ccacoalition.org/document/anaerobic-digester-project-screening-tool. Accessed November 7, 2019.

CCAC. 2018b. Financing Readiness Questionnaire. Climate and Clean Air Coalition Municipal Solid Waste Initiative. https://www.waste.ccacoalition.org/document/financing-readiness-questionnaire. Accessed November 7, 2019.

CCAC. 2018c. Policy Report: High-Level Pre-Feasibility Study and Implementation Plan for an Organic Waste Treatment Project in the Municipality of Quito. Climate and Clean Air Coalition. https://www.waste.ccacoalition.org/document/high-level-pre-feasibility-study-and-implementation-plan-organic-waste-treatment-project. Accessed May 19, 2020.

CCAC. 2018d. Using Internal Revenue Streams and External Financing for Solid Waste Management Projects. Climate and Clean Air Coalition Municipal Solid Waste Initiative. https://www.waste.ccacoalition.org/document/using-internal-revenue-streams-and-external-financing-solid-waste-management-projects. Accessed November 7, 2019.

CCAC. 2020. City MSW Rapid Assessment Data Collection Tool: ENGLISH. Climate and Clean Air Coalition Municipal Solid Waste Initiative Platform. https://www.waste.ccacoalition.org/document/city-msw-rapid-assessment-data-collection-tool-english. Accessed May 19, 2020.

CCAC. Undated(a). Municipal Solid Waste Knowledge Platform. Cities. Climate and Clean Air Coalition Municipal Solid Waste Initiative. https://www.waste.ccacoalition.org/participant. Accessed October 28, 2019.

CCAC. Undated(b). Municipal Solid Waste Knowledge Platform. Tools. Climate and Clean Air Coalition Municipal Solid Waste Initiative. https://www.waste.ccacoalition.org/tool. Accessed October 28, 2019.

CCAC. Undated(c). Raising Awareness About Solid Waste Management. http://www.waste.ccacoalition.org/file/1909/download?token=lE-unsJJ. Accessed April 27, 2020.

CCAC. Undated(d). The Manure Knowledge Kiosk. Climate and Clean Air Coalition. http://www.manurekiosk.org/. Accessed November 11, 2019.

CCAC. Undated(e). Waste. Mitigating Short-Lived Climate Pollutants from the Municipal Solid Waste Sector. Climate and Clean Air Coalition. https://www.ccacoalition.org/en/initiatives/waste. Accessed May 22, 2020.

CCAC and ISWA. 2016a. Strategy for Organic Waste Diversion – Collection, Treatment, Recycling and Their Challenges and Opportunities for the City of Sao Paulo, Brazil. Climate and Clean Air Coalition and International Solid Waste Association. https://www.ccacoalition.org/en/resources/strategy-organic-waste-diversion-collection-treatment-recycling-and-their-challenges-and. Accessed November 7, 2019.

CCAC and ISWA. 2016b. Technical Guidance on the Operation of Organic Waste Management Treatment Plants. Climate and Clean Air Coalition and International Solid Waste Association. https://www.ccacoalition.org/en/resources/technical-guidance-operation-organic-waste-treatment-plants. Accessed November 7, 2019.

CCAC and U.S. EPA. 2018. Best Practices for Waste Characterisation. Webinar. Climate and Clean Air Coalition and United States Environmental Protection Agency, Washington, DC. March 28. https://www.ccacoalition.org/en/event/webinar-best-practices-waste-characterisation-studies. Accessed November 7, 2019.

CEC. 2016. Environmentally Sound Management of Spent Lead-Acid Batteries in North America. Commission for Environmental Cooperation. January. http://www3.cec.org/islandora/en/item/11665-environmentally-sound-management-spent-lead-acid-batteries-in-north-america-en.pdf. Accessed November 11, 2019.

CECC. 2020. Center of Excellence for Circular Economy and Climate Change website. https://centercecc.org/. Accessed May 19, 2020.

CGF. 2018. Consumer Goods Forum's Waste Booklet. https://www.theconsumergoodsforum.com/wp-content/uploads/2017/10/Environmental-Sustainability-Food-Waste-Booklet-2018.pdf. Accessed February 7, 2020.

CGF. 2020. Food Waste: A Global Commitment to Halving Food Waste by 2025. Consumer Goods Forum. https://www.theconsumergoodsforum.com/initiatives/environmental-sustainability/key-projects/food-solid-waste/. Accessed January 28, 2020.

Chengappa, C. 2013. Organizing Informal Waste Pickers: A Case Study of Bengaluru, India. Women in Informal Employment: Globalizing and Organizing (WIEGO), Cambridge, MA. March. https://www.wiego.org/resources/organizing-informal-waste-pickers-case-study-bengaluru-india. Accessed November 7, 2019.

Ciudad Saludable. Undated. Ciudad Saludable website. http://www.ciudadsaludable.org/. Accessed February 3, 2020.

Cointreau, S. 2004. Sanitary Landfill Design and Siting Criteria. Guidance published in May 1996 by The World Bank as an Urban Infrastructure Note, updated November 2004. http://documents.worldbank.org/curated/en/461871468139209227/Sanitary-landfill-design-and-siting-criteria. Accessed November 7, 2019.

Coursera. 2019. Municipal Solid Waste Management in Developing Countries. Online course. https://www.coursera.org/learn/solid-waste-management. Accessed October 28, 2019.

CPHEEO. 2016. Municipal Solid Waste Management Manual. Central Public Health and Environmental Engineering Organisation. http://cpheeo.gov.in/upload/uploadfiles/files/Part2.pdf. Accessed April 27, 2020.

Dias, S.M. 2011. Overview of Legal Framework for Inclusion of Informal Recyclers in Brazil. Women in Informal Employment: Globalizing and Organizing. May. http://www.inclusivecities.org/wp-content/uploads/2012/07/Dias_WIEGO_PB6.pdf. Accessed November 7, 2019.

D-WASTE. 2020. Waste Atlas. http://www.atlas.d-waste.com/. Accessed January 31, 2020.

Eunomia. Undated. Plastics in the Marine Environment: Where Do They Come From? Where Do They Go? http://www.eunomia.co.uk/wp-content/uploads/2016/05/Eunomia-Marine-Litter-MED.jpg. Accessed October 22, 2019.

FAO. 2013. Toolkit: Reducing the Food Wastage Footprint. Food Wastage Footprint Project. Food and Agriculture Organization of the United Nations. http://www.fao.org/3/i3342e/i3342e.pdf. Accessed November 7, 2019.

FAO. 2020. Food Loss Analysis Reports and Fact Sheets. Food and Agriculture Organization of the United Nations. http://www.fao.org/food-loss-reduction/resources/faofoodlossanalysisreports/en/. Accessed January 31, 2020.

Farvacque-Vitkovic, C. and M. Kopanyi. 2014. Municipal Finances: A Handbook for Local Governments. The World Bank, Washington, DC. https://openknowledge.worldbank.org/handle/10986/18725. Accessed November 7, 2019.

Flanagan, K., K. Robertson, and C. Hanson. 2019. Reducing Food Loss and Waste: Setting a Global Action Agenda. World Resources Institute and The Rockefeller Foundation. https://wriorg.s3.amazonaws.com/s3fs-public/reducing-food-loss-waste-global-action-agenda_0.pdf. Accessed November 7, 2019.

Gerdes, P. and E. Gunsilius. 2010. The Waste Experts: Enabling Conditions for Informal Sector Integration in Solid Waste Management. Lessons Learned from Brazil, Egypt and India. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Eschborn/Deutschland. https://www.giz.de/en/downloads/gtz2010-waste-experts-conditions-is-integration.pdf. Accessed November 7, 2019.

GIZ. 2012. Economic Instruments in Solid Waste Management: Case Study – Maputo, Mozambique. Deutsche Gesellschaft für Internationale Zusammenarbeit. https://www.giz.de/en/downloads/giz2012-en-economic-instruments-mozambique.pdf. Accessed January 28, 2020.

Global Alliance of Waste Pickers. Undated. Global Alliance of Waste Pickers. https://globalrec.org/. Accessed February 3, 2020.

GMI. 2012. International Best Practices Guide for Landfill Gas Energy Projects. Global Methane Initiative, United States Environmental Protection Agency, and International Solid Waste Association. https://www.globalmethane.org/documents/toolsres_lfg_IBPGcomplete.pdf. Accessed November 7, 2019.

GMI. 2020. Biogas Sector Tools and Resources. Global Methane Initiative. https://www.globalmethane.org/tools-resources/resources_filtered.aspx?s=biogas. Accessed January 31, 2020.

GMI. Undated(a). Biogas. Featured Tools and Resources. Global Methane Initiative. https://www.globalmethane.org/tools-resources/resources_filtered.aspx?s=biogas. Accessed October 28, 2019.

GMI. Undated(b). Municipal Solid Waste. Plans and Actions. Global Methane Initiative. https://www.globalmethane.org/sectors/technicalgroup.aspx?s=msw. Accessed November 4, 2019.

GMI. Undated(c). Naucalpan de Juarez, Mexico – Improving Waste Management Practices and Reducing Methane Emissions. Global Methane Initiative. https://www.globalmethane.org/challenge/naucalpan.html. Accessed November 4, 2019.

GMI. Undated(d). Tools and Resources Archive. Global Methane Initiative. https://www.globalmethane.org/tools-resources/archive/index.aspx. Accessed October 28, 2019.

GMI. Undated(e). Tools and Resources. Featured Tools and Resources. Global Methane Initiative. https://www.globalmethane.org/tools-resources/resources_filtered.aspx. Accessed May 19, 2020.

Gómez-Brandón, M., M. Fernández-Delgado Juárez, J. Domínguez, and H. Insam. 2013. Animal manures: Recycling and management technologies. In Biomass Now: Cultivation and Utilization. pp. 237272. https://www.intechopen.com/books/biomass-now-cultivation-and-utilization/animal-manures-recycling-and-management-technologies. Accessed February 4, 2020.

Government of India. 2016. Solid Waste Management Rules 2016. Ministry of Environment, Forest, and Climate Change, New Delhi, India. https://kspcb.gov.in/SWM-Rules-2016.pdf. Accessed November 7, 2019.

Hasiru Dala. 2015. Hasiru Dala website. https://hasirudala.in/krishna-2/. Accessed November 7, 2019.

Hinkel, M. and S. Blume. 2018. The Role of Pre- and Co-Processing in Sustainable Waste Management. Presented at the ISWA World Conference in Kuala Lumpur, Malaysia. https://www.iswa.org/media/publications/knowledge-base/login-and-registration/kb_account//5206/?tx_iswaknowledgebase_filter%5Bcategories%5D=all&tx_iswaknowledgebase_filter%5Bmaincategories%5D=0%2C1&tx_iswaknowledgebase_searchbox%5Bsearchphrase%5D=co-processing&tx_iswaknowledgebase_list%5Bpage%5D=1&tx_iswaknowledgebase_list%5Bsorting%5D=crdate&cHash=0ae6b4bfdb0304b4e85ac8a4bbed012b. Accessed January 28, 2019.

Hinshaw, D. 2015. How Plastic Bags Are Clogging Accra, Exacerbating Deadly Floods. News Ghana. June 23. https://www.newsghana.com.gh/how-plastic-bags-are-clogging-accra-exacerbating-deadly-floods/. Accessed November 7, 2019.

IAEA. 2008. Guidelines for Sustainable Manure Management in Asian Livestock Production Systems. May. International Atomic Energy Agency. https://www-pub.iaea.org/MTCD/Publications/PDF/TE_1582_web.pdf. Accessed November 11, 2019.

IDB. 2016. Solid Waste Management in the Caribbean: Proceedings from the Caribbean Solid Waste Conference. April. Inter-American Development Bank. https://pdfs.semanticscholar.org/7617/f0c0a0cca771a39bb6510232d980953975a9.pdf. Accessed January 28, 2020.

IFC. 2013. Public-Private Partnership Stories. West Bank & Gaza: Solid Waste Management. International Finance Corporation, Washington, DC. November. https://www.ifc.org/wps/wcm/connect/e9b7ed6a-c842-473a-b35b-9365b99699a0/PPPStories_WestBankGaza_SolidWasteManagement.pdf?MOD=AJPERES&CVID=lHIBKti. Accessed May 19, 2020.

IGES. 2019. Challenges and an Implementation Framework for Sustainable Municipal Organic Waste Management Using Biogas Technology in Emerging Asian Countries. Institute for Global Environmental Strategies. https://www.iges.or.jp/en/pub/challenges-and-implementation-framework-sustainable-municipal-organic-waste-management-using. Accessed May 1, 2020.

IGES and UNEP. 2017. Planning and Implementation of Integrated Solid Waste Management Strategies at the Local Level: The Case of Cebu City. Institute for Global Environmental Strategies and United Nations Environmental Programme. https://www.iges.or.jp/en/publication_documents/pub/training/en/6039/CCET+Cebu+Case+Study_PrintingVer0718_2.pdf. Accessed May 1, 2020.

IGES and UNEP. 2018. Participatory Waste Management Approach for Climate Change Mitigation: The Case of Battambang City. Institute for Global Environmental Strategies and United Nations Environmental Programme. https://www.waste.ccacoalition.org/document/case-study-battambang-cambodia-ccet. Accessed February 4, 2020.

IGES and UNEP. 2020. Strategies to Reduce Marine Plastic Pollution from Land-Based Sources in Low and Middle-Income Countries. Institute for Global Environmental Strategies and United Nations Environmental Programme. https://www.iges.or.jp/en/pub/strategies-reduce-marine-plastic-pollution-land-based-sources-low-and-middle-income-countries. Accessed May 1, 2020.

ILO. 2019. A First Step Towards Improving Working Conditions of Waste Pickers in Senegal. International Labour Organization. https://www.ilo.org/global/topics/cooperatives/news/WCMS_721510/lang--en/index.htm. Accessed February 3, 2020.

ISO. 2020. Recycling. International Organization for Standardization. https://www.iso.org/ics/13.030.50/x/. Accessed April 27, 2020.

ISWA. 2010. Landfill Operational Guidelines. 2nd Edition. International Solid Waste Association Working Group on Landfill. January. http://www.iswa.org/index.php?eID=tx_iswaknowledgebase_download&documentUid=1449. Accessed November 7, 2019.

ISWA. 2011. International Guidelines for Landfill Evaluation. International Solid Waste Association Working Group on Landfill. September. http://www.iswa.org/index.php?eID=tx_iswaknowledgebase_download&documentUid=2136. Accessed November 7, 2019.

ISWA. 2013a. Food Waste as a Global Issue – from the Perspective of Municipal Solid Waste Management. Key Issue Paper. July. International Solid Waste Association Working Group on the Biological Treatment of Waste. https://www.iswa.org/index.php?eID=tx_bee4mememberships_download&fileUid=185. Accessed November 7, 2019.

ISWA. 2013b. ISWA Guidelines: Waste to Energy in Low and Middle Income Countries. August. International Solid Waste Association Working Group on Energy Recovery. http://www.iswa.org/index.php?eID=tx_iswaknowledgebase_download&documentUid=3252. Accessed November 7, 2019.

ISWA. 2015. Wasted Health: The Tragic Case of Dumpsites. June. International Solid Waste Association Scientific and Technical Committee Work Program 2014–2015. https://www.iswa.org/fileadmin/galleries/Task_Forces/THE_TRAGIC_CASE_OF_DUMPSITES.pdf Accessed April 29, 2020.

ISWA. 2016. A Roadmap for Closing Waste Dumpsites: The World's Most Polluted Places. International Solid Waste Association. https://www.iswa.org/fileadmin/galleries/About%20ISWA/ISWA_Roadmap_Report.pdf. Accessed November 7, 2019.

ISWA. 2017a. Closing Dumpsites Knowledge Base. International Solid Waste Association. http://closingdumpsites.iswa.org/get-support/knowledge-base/. Accessed October 28, 2019.

ISWA. 2017b. Let's Close the World's Biggest Dumpsites! International Solid Waste Association. http://closingdumpsites.iswa.org/. Accessed October 28, 2019.

ISWA. 2017c. Primer for Cities for Accessing Financing for Municipal Solid Waste Projects. International Solid Waste Association. https://www.waste.ccacoalition.org/document/primer-cities-accessing-financing-municipal-solid-waste-projects. Accessed November 7, 2019.

ISWA. 2019. Landfill Operational Guidelines. International Solid Waste Association. https://www.iswa.org/index.php?eID=tx_iswaknowledgebase_download&documentUid=5237. Accessed April 27, 2020.

Jakobsen, L.G. 2012. Waste Characterization in Rural Areas in Developing Countries with a Case Study in Sundarban, West Bengal, India. June. Bachelor Thesis, DTU Environment. http://www.innoaid.org/wp-content/uploads/2014/09/Line-Geest-Jakobsen-s091672-Waste-Characterization-in-Rural-Areas-in-Developing-Countries-with-a-Case-Study-in-Sundarban-West-Bengal-India.pdf. Accessed November 7, 2019.

JICA. 2012. Data Collection Survey on Solid Waste Management Sector in the Central American and Caribbean Region. Japan International Cooperation Agency. http://open_jicareport.jica.go.jp/pdf/12091898.pdf. Accessed November 11, 2019.

Johannessen, L.M. and G. Boyer. 1999. Observations of Solid Waste Landfills in Developing Countries: Africa, Asia, and Latin America. World Bank Group. https://pdfs.semanticscholar.org/55c1/847025be7a9162f87ee3df9e30fabeb5dc08.pdf. Accessed November 11, 2019.

Karthik, D. 2018. QR Code to Track Trichy's Waste Collection. Time of India. September 2. https://timesofindia.indiatimes.com/city/trichy/qr-code-to-track-trichys-waste-collection/articleshow/65640238.cms. Accessed November 7, 2019.

Kaza, S., L. Yao, P. Bhada-Tata, and F. Van Woerden. 2018. What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. World Bank Group, Washington, DC. https://openknowledge.worldbank.org/handle/10986/30317. Accessed November 7, 2019.

Kogler, T. 2007. Waste Collection: A Report. International Solid Waste Association. https://www.waste.ccacoalition.org/document/waste-collection. Accessed November 7, 2019.

Kojima, M., A. Yoshida, and S. Sasaki. 2009. Difficulties in applying extended producer responsibility policies in developing countries: Case studies in e-waste recycling in China and Thailand. Journal of Material Cycles and Waste Management 11:263–269.

Komakech, A., N. Banadda, J. Kinobe, L. Kasisira, C. Sundberg, G. Gebresenbet, and B. Vinneras. 2014. Characterization of municipal solid waste in Kampala, Uganda. Journal of the Air & Waste Management Association 64:340–348. https://www.tandfonline.com/doi/full/10.1080/10962247.2013.861373. Accessed February 4, 2020.

Malomo, G., A. Madugu, and S. Bolu. 2013. Sustainable animal manure management strategies and practices. In Agricultural Waste and Resides. pp. 119–137. https://www.intechopen.com/books/agricultural-waste-and-residues/sustainable-animal-manure-management-strategies-and-practices. Accessed February 4, 2020.

Matthews, E., C. Amann, S. Bringezu, M. Fischer-Kowalski, W. Huttler, R. Kleijn, Y. Moriguchi, C. Ottke, E. Rodenburg, D. Rogich, H. Schandl, H. Schűtz, E. Van der Voet, and H. Weisz. 2000. The Weight of Nations: Material Outflows from Industrial Economies. World Resources Institute, Washington, DC. http://pdf.wri.org/weight_of_nations.pdf. Accessed November 7, 2019.

Munawar, E. and J. Fellner. 2013. Guidelines for Design and Operation of Municipal Solid Waste Landfills in Tropical Climates. February. International Solid Waste Association. http://www.iswa.org/index.php?eID=tx_iswaknowledgebase_download&documentUid=3159. Accessed November 7, 2019.

Mutz, D., D. Hengevoss, C. Hugi, and T. Gross. 2017. Waste-to-Energy Options in Municipal Solid Waste Management. A Guide for Decision Makers in Developing and Emerging Countries. May. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Eschborn. https://www.giz.de/en/downloads/GIZ_WasteToEnergy_Guidelines_2017.pdf. Accessed November 7, 2019.

Njoku, N., J. Lamond, G. Everett, and P. Manu. 2015. An Overview of Municipal Solid Waste Management in Developing and Developed Economies: Analysis of Practices and Contributions to Urban Flooding in Sub-Saharan Africa. Presented at the 12th International Post-Graduate Research Conference at Salford, UK. https://www.researchgate.net/publication/279868600_An_Overview_of_Municipal_Solid_Waste_Management_in_Developing_and_Developed_Economies_Analysis_of_Practices_and_Contributions_to_Urban_Flooding_in_Sub-Saharan_Africa. Accessed November 11, 2019.

NOAA. 2019. Sources. National Oceanic and Atmospheric Administration Marine Debris Program, Office of Response and Restoration. Revised November 6, 2019. https://marinedebris.noaa.gov/types-and-sources/sources. Accessed November 7, 2019.

Ocean Conservancy. 2019. Fighting for Trash Free Seas: Ending the Flow of Trash at the Source. https://oceanconservancy.org/trash-free-seas/. Accessed October 22, 2019.

Ocean Conservancy and Trash Free Seas Alliance. 2019. Plastics Policy Playbook: Strategies for a Plastic-Free Ocean. https://oceanconservancy.org/wp-content/uploads/2019/10/Plastics-Policy-Playbook-10.17.19.pdf. Accessed January 31, 2020.

OECD LEED Programme. 2014. Chile's Pathway to Green Growth: Measuring Progress at Local Level. Organization for Economic Co-operation and Development Local Economic and Employment Development Programme. https://www.oecd.org/cfe/leed/Green_growth_Chile_Final2014.pdf. Accessed November 7, 2019.

O'Leary, P. and P. Walsh. 1991. Example Sanitary Landfill Design Illustration. Reprinted from Waste Age correspondence course articles. University of Wisconsin–Madison Solid and Hazardous Waste Education Center.

Pehlken, A. and E. Essadiqi. 2005. Scrap Tire Recycling in Canada. August. CANMET Materials Technology Laboratory. https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/mineralsmetals/pdf/mms-smm/busi-indu/rad-rad/pdf/scr-tir-rec-peh-eng.pdf. Accessed November 11, 2019.

PETCO. 2020. PETCO website. https://petco.co.za/. Accessed January 28, 2020.

PPP Knowledge Lab. 2019. What is a PPP: Defining "Public-Private Partnership." The World Bank Group. https://pppknowledgelab.org/guide/sections/3-what-is-a-ppp-defining-public-private-partnership. Accessed November 7, 2019.

Reciclo Organicos. 2020. Reciclo Organicos Program. https://www.reciclorganicos.com/. Accessed May 1, 2020.

Richards, E. and D. Haynes. 2014. Solid waste management in Pacific Island countries and territories. In Municipal Solid Waste Management in Asia and the Pacific Islands, edited by A. Pariatamby and M. Tanaka. Springer, Singapore. pp. 255–279. https://link.springer.com/chapter/10.1007/978-981-4451-73-4_13. Accessed November 11, 2019.

Savage, G.M., L.F. Diaz, C.G. Golueke, and C. Martone. 1998. Guidance for Landfilling Waste in Economically Developing Countries. EPA-600/R-09-040. April. United States Environmental Protection Agency. https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=91017GP2.txt. Accessed November 7, 2019.

Shuster, K.A. 1974. A Five Stage Improvement Process for Solid Waste Collection Systems. United States Environmental Protection Agency, Washington, DC. https://nepis.epa.gov/Exe/ZyPDF.cgi/9100RVVR.PDF?Dockey=9100RVVR.PDF. Accessed November 7, 2019.

Skoll. 2006. Ciudad Saludable. Skoll Awardee Profile: Organization Overview. Skoll. http://skoll.org/organization/ciudad-saludable/. Accessed February 3, 2020.

Tchobanoglous, G. and F. Kreith. 2002. Handbook of Solid Waste Management. Second Edition. McGraw-Hill, New York. https://sanitarac.pro/wp-content/uploads/2017/07/Solid-Waste-Management.pdf. Accessed November 7, 2019.

TERI. 2020a. Composting and Anaerobic Digestion: Promising Technologies for Organic Waste Management. The Energy and Resources Institute. https://www.teriin.org/sites/default/files/files/white-paper-composting-anaerobic-digestion.pdf. Accessed May 1, 2020.

TERI. 2020b. Waste. The Energy and Resources Institute. https://www.teriin.org/waste. Accessed May 1, 2020.

UNEP. 2005a. Solid Waste Management. United Nations Environment Programme and CalRecovery Inc. https://www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/E-Learning/Moocs/Solid_Waste/W2/Solid_waste_management_UNEP_2005.pdf. Accessed November 7, 2019.

UNEP. 2005b. Training Module: Closing an Open Dumpsite and Shifting from Open Dumping to Controlled Dumping and to Sanitary Land Filling. United Nations Environment Programme. https://wedocs.unep.org/bitstream/handle/20.500.11822/8444/SPC_Training_Module_1.pdf?sequence=3&isAllowed=y. Accessed November 7, 2019.

UNEP. 2009a. Developing Integrated Solid Waste Management Plan, Training Manual; Volume 1: Waste Characterization and Quantification with Projections for Future. United Nations Environment Programme. http://wedocs.unep.org/bitstream/handle/20.500.11822/7502/ISWMPlan_Vol1.pdf?sequence=3&isAllowed=y. Accessed November 7, 2019.

UNEP. 2009b. Developing Integrated Solid Waste Management Plan, Training Manual; Volume 2: Assessment of Current Waste Management System and Gaps Therein. United Nations Environment Programme. https://wedocs.unep.org/bitstream/handle/20.500.11822/7609/ISWMPlan_Vol2.pdf?sequence=3&amp%3BisAllowed=. Accessed November 7, 2019.

UNEP. 2009c. Developing Integrated Solid Waste Management Plan, Training Manual; Volume 4: ISWM Plan. United Nations Environment Programme. http://wedocs.unep.org/bitstream/handle/20.500.11822/7770/ISWMPlan_Vol4.pdf?sequence=3&isAllowed=y. Accessed November 7, 2019.

UNEP. 2011. Technical Guidelines for the Environmentally Sound Management of Used and Waste Pneumatic Tyres. October. United Nations Environment Programme. https://www.etrma.org/wp-content/uploads/2019/09/2011-10-31_technical-guidelines-on-esm-of-used-tyres_adopted-at-cop10_advance.pdf. Accessed November 11, 2019.

UNEP. 2013. Revised Guideline on Environmentally Sound Material Recovery and Recycling of End-of-Life Computing Equipment. http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW.11-INF-13-Rev.1.English.pdf. Accessed November 11, 2019.

UNEP. 2015. Practical Sourcebook on Mercury Waste Storage and Disposal. United Nations Environment Programme. November. https://wedocs.unep.org/bitstream/handle/20.500.11822/9839/-Practical_Sourcebook_on_Mercury_Waste_Storage_and_Disposal-2015Sourcebook_Mercruy_FINAL_web.pdf.pdf?sequence=3&isAllowed=y. Accessed May 21, 2020.

UNEP. 2018a. Disaster Waste Management Policy/Strategy Nepal. United Nations Environment Programme. November. https://www.unenvironment.org/ietc/resources/policy-and-strategy/disaster-waste-management-policystrategy-nepal. Accessed May 19, 2020.

UNEP. 2018b. Single-Use Plastics: A Roadmap for Sustainability. United Nations Environment Programme. https://wedocs.unep.org/bitstream/handle/20.500.11822/25496/singleUsePlastic_sustainability.pdf. Accessed January 28, 2020.

UNEP. 2018c. Waste Management Outlook for Latin American and the Caribbean. United Nations Environment Programme. https://wedocs.unep.org/bitstream/handle/20.500.11822/26448/Residuos_LAC_EN.pdf?sequence=2&isAllowed=y. Accessed January 31, 2020.

UNEP. 2019. Waste-to-Energy: Considerations for Informed Decision-Making. United Nations Environment Programme. http://wedocs.unep.org/bitstream/handle/20.500.11822/28413/WTEfull.pdf?sequence%E2%80%A6. Accessed November 7, 2019.

UNEP. Undated(a). Global Partnership on Marine Litter. United Nations Environment Programme. https://www.unenvironment.org/explore-topics/oceans-seas/what-we-do/addressing-land-based-pollution/global-partnership-marine. Accessed October 22, 2019.

UNEP. Undated(b). Lead Acid Batteries. United Nations Environment Programme. https://www.unenvironment.org/sw/node/8126. Accessed November 11, 2019.

UNEP. Undated(c). The Caribbean Environment Programme and Cartagena Convention Secretariat. Protecting our Caribbean Sea and Sustaining Our Future. United Nations Environment Programme. https://www.unenvironment.org/cep/. Accessed October 22, 2019.

UNEP. Undated(d). Training Manual for the Preparation of Used Lead Acid Batteries National Management Plans. Basel Convention Training Manual. United Nations Environment Programme. https://www.minzp.sk/files/oblasti/odpady-a-obaly/medzinarodne-dohovory/publikacie-bazilejskeho-dohovoru/12-Lead-acid_Batteries_Training.pdf. Accessed November 11, 2019.

UNEP and ISWA. 2015. Global Waste Management Outlook. United Nations Environment Programme and International Solid Waste Association. https://wedocs.unep.org/bitstream/handle/20.500.11822/9672/-Global_Waste_Management_Outlook-2015Global_Waste_Management_Outlook.pdf.pdf?sequence=3&isAllowed=. Accessed November 7, 2019.

UN-Habitat. 2010. Collection of Municipal Solid Waste in Developing Countries. https://www.ccacoalition.org/en/resources/collection-municipal-solid-waste-developing-countries. Accessed November 7, 2019.

UN-Habitat. 2011. Recycling and Disposal of Municipal Solid Waste in Low and Middle-Income Countries. Perspectives for Municipal Managers and Environment Agencies. UN-Habitat, Kenya. http://mirror.unhabitat.org/downloads/docs/Recycling%20and%20disposal%20of%20solid%20waste%20in%20low%20and%20middle-income%20countries.pdf. Accessed November 7, 2019.

Unilever Indonesia. Undated. Environment Programme. https://www.unilever.co.id/en/about/unilever-indonesia-foundation/environment-programme.html. Accessed October 28, 2019.

University of Texas at Arlington. 2015. Mission. Organized Research Center of Excellence – Solid Waste Institute for Sustainability. https://www.uta.edu/swis/index.html. Accessed May 19, 2020.

USAID. 2015. Sector Environmental Guidelines Healthcare Waste. United States Agency for International Development. Partial Update 2015. https://www.usaid.gov/environmental-procedures/sectoral-environmental-social-best-practices/seg-healthcare-waste/pdf. Accessed November 11, 2019.

USAID. 2018. Sector Environmental Guideline: Solid Waste. United States Agency for International Development. Full Technical Update December. https://www.usaid.gov/sites/default/files/documents/1860/SectorEnvironmentalGuidelines_SolidWaste_2018.pdf. Accessed November 7, 2019.

USAID. 2019a. Global Development Alliances. Updated April 12. United States Agency for International Development. https://www.usaid.gov/gda. Accessed November 7, 2019.

USAID. 2019b. Reducing Mismanaged Plastic Waste through Healthier Waste Entrepreneurs. June. United States Agency for International Development. https://www.usaid.gov/gda. Accessed May 21, 2019.

USAID. 2019c. Sector Environmental Guidelines: Healthcare Waste. Full Technical Update. United States Agency for International Development. November. https://www.usaid.gov/sites/default/files/documents/1864/FINAL_HCW_SEG_508_12.02.19.pdf. Accessed May 21, 2020.

USAID. Undated. Environmental Guidelines for the USAID Latin America and Caribbean Bureau. United States Agency for International Development. https://usaidgems.org/sectorGuidelinesLAC.htm. Accessed November 11, 2019.

U.S. DOE. 2019. Waste-to-Energy from Municipal Solid Wastes. August. United States Department of Energy. https://www.energy.gov/sites/prod/files/2019/08/f66/BETO--Waste-to-Energy-Report-August--2019.pdf. Accessed January 28, 2020.

U.S. EPA. 1995. Decision-Maker's Guide to Solid Waste Management, Volume II. EPA530-R-95-023. August. United States Environmental Protection Agency, Washington, DC. https://nepis.epa.gov/Exe/ZyPDF.cgi/10000VWJ.PDF?Dockey=10000VWJ.PDF. Accessed November 7, 2019.

U.S. EPA. 2002a. Solid Waste Management: A Local Challenge with Global Impacts. EPA530-F-02-026. May. United States Environmental Protection Agency, Washington, DC. https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=10000KWD.txt. Accessed November 7, 2019.

U.S. EPA. 2002b. Waste Transfer Stations: A Manual for Decision-Making. EPA530-R-02-002. June. United States Environmental Protection Agency, Washington, DC. https://www.epa.gov/landfills/waste-transfer-stations-manual-decision-making. Accessed November 7, 2019.

U.S. EPA. 2009. Sustainable Materials Management: The Road Ahead. EPA530-R-09-009. June. United States Environmental Protection Agency, Washington, DC. https://www.epa.gov/sites/production/files/2015-09/documents/vision2.pdf. Accessed November 7, 2019.

U.S. EPA. 2010. Scrap Tires: Handbook on Recycling Applications and Management for the U.S. and Mexico. EPA530-R-10-010. December. United States Environmental Protection Agency, Washington, DC. https://nepis.epa.gov/Exe/ZyPDF.cgi/P100ACUU.PDF?Dockey=P100ACUU.PDF. Accessed November 11, 2019.

U.S. EPA. 2011. International Environmental Finance Tools. United States Environmental Protection Agency. https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100B9IY.TXT. Accessed February 7, 2020.

U.S. EPA. 2015. Best Management Practices for Optimizing Waste Collection Routes. Memorandum, February 12, from Sandra Mazo-Nix and Dana Murray, SCS Engineers, to Zaidoun ElQasem. Prepared for the Climate & Clean Air Coalition's Waste Initiative, Amman, Jordan. United States Environmental Protection Agency. https://www.waste.ccacoalition.org/document/best-management-practices-optimizing-waste-collection-routes. Accessed November 7, 2019.

U.S. EPA. 2016a. Environmental Factoids. United States Environmental Protection Agency. https://archive.epa.gov/epawaste/conserve/smm/wastewise/web/html/factoid.html. Accessed February 3, 2020.

U.S. EPA. 2016b. Frequent Questions about Anaerobic Digestion. Last updated October 3, 2016. United States Environmental Protection Agency. https://www.epa.gov/anaerobic-digestion/frequent-questions-about-anaerobic-digestion. Accessed November 7, 2019.

U.S. EPA. 2016c. OrganEcs – Cost Estimating Tool for Managing Source-Separated Organic Waste – Version 2.1. Prepared for the Climate and Clean Air Coalition Municipal Solid Waste Initiative. United States Environmental Protection Agency. https://www.waste.ccacoalition.org/document/organecs-cost-estimating-tool-managing-source-separated-organic-waste-version-21. Accessed November 7, 2019.

U.S. EPA. 2016d. Wastes - Non-Hazardous Waste - Municipal Solid Waste. Last Updated March 26, 2016. United States Environmental Protection Agency. https://archive.epa.gov/epawaste/nonhaz/municipal/web/html/basic.html. Accessed January 28, 2020.

U.S. EPA. 2016e. Wastes – Resource Conservation – Common Wastes & Materials – Scrap Tires. Tire-Derived Fuel. Last updated February 22, 2016. United States Environmental Protection Agency. https://archive.epa.gov/epawaste/conserve/materials/tires/web/html/tdf.html. Accessed November 7, 2019.

U.S. EPA. 2017a. Ghazipur Landfill Rehabilitation Report. United States Environmental Protection Agency, Washington, DC. https://www.ccacoalition.org/en/resources/ghazipur-landfill-rehabilitation-report. Accessed November 7, 2019.

U.S. EPA. 2017b. Improving Solid Waste Disposal in San Cristobal Municipality, Dominican Republic. United States Environmental Protection Agency. https://response.epa.gov/sites/14055/files/CAFTA-DRSanCristobal_ENGLISH_2018-09-28.pdf. Accessed January 31, 2020.

U.S. EPA. 2017c. Managing and Transforming Waste Streams: A Tool for Communities. U.S. Environmental Protection Agency. https://www.epa.gov/transforming-waste-tool/managing-and-transforming-waste-streams-tool. Accessed November 7, 2019.

U.S. EPA. 2017d. Public Participation Guide. United States Environmental Protection Agency, Washington, DC. https://www.epa.gov/international-cooperation/public-participation-guide. Accessed November 7, 2019.

U.S. EPA. 2017e. Rio De Janeiro, Brazil: Mitigating Methane and Black Carbon from the Municipal Solid Waste Sector. Case Study. Prepared for the Climate and Clean Air Coalition. United States Environmental Protection Agency. https://www.waste.ccacoalition.org/document/case-study-rio-de-janeiro-brazil-ccac-waste-initiative. Accessed November 7, 2019.

U.S. EPA. 2017f. Sustainable Materials Management: Non-Hazardous Materials and Waste Management Hierarchy. Updated August 10, 2017. United States Environmental Protection Agency. https://www.epa.gov/smm/sustainable-materials-management-non-hazardous-materials-and-waste-management-hierarchy. Accessed November 7, 2019.

U.S. EPA. 2018a. Basic Information about Anaerobic Digestion (AD). Updated September 5, 2018. United States Environmental Protection Agency. https://www.epa.gov/anaerobic-digestion/basic-information-about-anaerobic-digestion-ad#HowADworks. Accessed November 7, 2019.

U.S. EPA. 2018b. Coalition Partners Assist Naucalpan, Mexico in Analyzing Waste Stream. Results to Inform Development of New Biogas Project. United States Environmental Protection Agency Climate & Clean Air Coalition. https://ccacoalition.org/en/news/coalition-partners-assist-naucalpan-mexico-analyzing-waste-stream. Accessed November 7, 2019.

U.S. EPA. 2018c. Improving Solid Waste Disposal in San Cristobal Municipality, Dominican Republic. U.S. Environmental Protection Agency. https://response.epa.gov/sites/14055/files/CAFTA-DRSanCristobal_ENGLISH_2018-09-28.pdf. Accessed January 28, 2020.

U.S. EPA. 2018d. Municipal Solid Waste Landfills. Updated September 13, 2018. United States Environmental Protection Agency. https://www.epa.gov/landfills/municipal-solid-waste-landfills. Accessed November 7, 2019.

U.S. EPA. 2018e. Sustainable Materials Management Options for Construction and Demolition Debris. EPA/601/R-18/001. United States Environmental Protection Agency, Cincinnati, OH. November. https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=342507&Lab=NRMRL&subject=Health%20Research&showCriteria=0&searchAll=Waste%20Management%20or%20Nitrogen%20Management%20or%20Contaminated%20Sites%20or%20Ground%20Water%20or%20Materials%20Manage. Accessed November 11, 2019.

U.S. EPA. 2018f. Waste Characterization Best Practices Guidance. Draft. Prepared by Abt Associates and SCS Engineers for the United States Environmental Protection Agency Climate & Clean Air Coalition's Municipal Solid Waste Initiative.

U.S. EPA. 2019a. Energy Recovery from the Combustion of Municipal Solid Waste (MSW). Updated October 22, 2019. United States Environmental Protection Agency. https://www.epa.gov/smm/energy-recovery-combustion-municipal-solid-waste-msw. Accessed November 7, 2019.

U.S. EPA. 2019b. Household Hazardous Waste (HHW). Updated May 2, 2019. United States Environmental Protection Agency. https://www.epa.gov/hw/household-hazardous-waste-hhw. Accessed November 11, 2019.

U.S. EPA. 2019c. Landfill Gas Basics. United States Environmental Protection Agency. https://www.epa.gov/lmop/basic-information-about-landfill-gas. Accessed January 31, 2020.

U.S. EPA. 2020a. Anaerobic Digestion (AD) website. United States Environmental Protection Agency. https://www.epa.gov/anaerobic-digestion. Accessed January 31, 2020.

U.S. EPA. 2020b. Hazardous Waste Generators. Updated May 22, 2020. United States Environmental Protection Agency. https://www.epa.gov/hwgenerators. Accessed June 16, 2020.

U.S. EPA. 2020c. Managing Your Hazardous Waste: A Guide for Small Businesses. Updated February 18, 2020. United States Environmental Protection Agency. https://www.epa.gov/hwgenerators/managing-your-hazardous-waste-guide-small-businesses. Accessed June 16, 2020.

WBA/C40. 2018. Global Food Waste Management: An Implementation Guide for Cities. Full Report. World Biogas Association and C40 Cities. http://www.worldbiogasassociation.org/wp-content/uploads/2018/05/Global-Food-Waste-Management-Full-report-pdf.pdf. Accessed November 7, 2019.

WEF. 2019. A New Circular Vision for Electronics. World Economic Forum. http://www3.weforum.org/docs/WEF_A_New_Circular_Vision_for_Electronics.pdf. Accessed February 3, 2020.

WHO. 2014. Safe Management of Wastes from Health-Care Activities. World Health Organization. https://www.who.int/water_sanitation_health/publications/wastemanag/en/. Accessed November 11, 2019.

WHO. 2017. Recycling Used Lead-Acid Batteries: Health Considerations. World Health Organization. https://www.who.int/ipcs/publications/ulab/en/. Accessed November 11, 2019.

WIEGO. 2019. Annual Report. April 2018–March 2019. Women in Informal Employment: Globalizing and Organizing (WIEGO). March. https://www.wiego.org/wiego-annual-reports. Accessed February 3, 2020.

WIEGO. 2020. Women in Informal Employment: Globalizing & Organizing. https://www.wiego.org/. Accessed February 3, 2020.

Wilson, D.C., C.A. Velis, and L. Rodic. 2013. Integrated sustainable waste management in developing countries. Waste and Resource Management 166 (WR2):52–68. https://www.icevirtuallibrary.com/doi/pdf/10.1680/warm.12.00005. Accessed November 7, 2019.

Wilson, D.C., A.O. Araba, K. Chinwah, and C.R. Cheeseman. 2009. Building recycling rates through the informal sector. Waste Management 29, no. 2 (February 29, 2009):629–635. 10.1016/j.wasman.2008.06.016.

World Bank. 2014. Results-Based Financing for Municipal Solid Waste. The World Bank. http://documents.worldbank.org/curated/en/237191468330923040/pdf/918610v20WP0FM0BE0CATALOGED0BY0WED0.pdf. Accessed January 28, 2020.

World Bank. 2016. Sustainable Financing and Policy Models for Municipal Composting. The World Bank, Washington, DC. https://www.waste.ccacoalition.org/document/sustainable-financing-and-policy-models-municipal-composting. Accessed February 4, 2020.

World Bank. 2019a. Municipal Solid Waste (MSW) PPPs. Public-Private-Partnership Legal Resource Center. The World Bank. Updated July 11, 2019. https://ppp.worldbank.org/public-private-partnership/sector/solid-waste. Accessed November 7, 2019.

World Bank. 2019b. What A Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. Tackling Increasing Plastic Waste. The World Bank. http://datatopics.worldbank.org/what-a-waste/tackling_increasing_plastic_waste.html. Accessed October 28, 2019.

World Bank Blog. 2019. Lessons from the West Bank's First PPP: Fragile State + Open Mind. March 13. https://blogs.worldbank.org/ppps/lessons-west-bank-s-first-ppp-fragile-state-open-mind. Accessed May 19, 2020.

Yagasa, R. and P. Gamaralalage. 2019. Ecology Note – Towards a Clean and Beautiful Capital City. Institute for Global Environmental Strategies. https://www.iges.or.jp/en/pub/ecology-note-towards-clean-green-and-beautiful/en. Accessed April 27, 2020.

Appendix A

Summary of Key Resources

Resource	Organization	Year	Relevant Sections
A New Circular Vision for Electronics	World Economic Forum	2019	*Recycling*
A Roadmap for Closing Waste Dumpsites: The World's Most Polluted Places	International Solid Waste Associations (ISWA)	2016	*Dumpsite Management*
Anaerobic Digester (AD) Project Screening Tool	United States Environmental Protection Agency (U.S. EPA) and Climate and Clean Air Coalition (CCAC)	2018	*Organic Waste Management*
Best Management Practices for Optimizing Waste Collection Routes	U.S. EPA and CCAC	2015	*Separation, Collection, and Transportation*
Best Practices for Waste Characterization	U.S. EPA and CCAC	2018	*Characterization*
Climate and Clean Air Coalition Municipal Solid Waste Knowledge Platform	CCAC	Undated	*Organic Waste Management*; *Dumpsite Management*; *Sanitary Landfills*
Closing Dumpsites Knowledge Base	ISWA	2017	*Dumpsite Management*
Collection of Municipal Solid Waste in Developing Countries	UN-Habitat	2011	*Separation, Collection, and Transportation*
Consumer Goods Forum: Food Waste	The Consumer Goods Forum	2020	*Prevention and Minimization*
Decision-Maker's Guide to Solid Waste Management, Volume II	U.S. EPA	1995	*Stakeholder Engagement*; *Planning Systems*
Developing Integrated Solid Waste Management Plan, Training Manual; Volume 1: Waste Characterization and Quantification with Projections for Future	United Nations Environment Programme (UNEP)	2009	*Characterization*
Developing Integrated Solid Waste Management Plan, Volume 2: Assessment of Current Waste Management System and Gaps Therein	UNEP	2009	*Planning Systems*
Developing Integrated Solid Waste Management Plan, Training Manual; Volume 4: Integrated Solid Waste Management Plan	UNEP	2009	*Planning Systems*
Explainer: How to finance urban infrastructure?	C40 Cities	2017	*Economic Considerations*
Fighting for Trash Free Seas: Ending the Flow of Trash at the Source	Ocean Conservancy	2019	*Marine Litter*

Resource	Organization	Year	Relevant Sections
Financing Readiness Questionnaire	U.S. EPA and CCAC	2018	Economic Considerations
Food Loss Analysis Reports and Fact Sheets	Food and Agriculture Organization of the United Nations	2020	Prevention and Minimization
Food Waste as a Global Issue – From the Perspective of Municipal Solid Waste Management	ISWA	2013	Prevention and Minimization
Global Alliance of Waste Pickers	Global Alliance of Waste Pickers	Undated	Informal Sector Recycling
Global Waste Management Outlook	UNEP and ISWA	2015	Understanding the Need for Solid Waste Management
Global Development Alliances	United States Agency for International Development	2019a	Economic Considerations
Global Food Waste Management: An Implementation Guide for Cities	World Biogas Association and C40 Cities	2018	Organic Waste Management
Global Methane Initiative: Biogas Tools and Resources	Global Methane Initiative	2020	Organic Waste Management; Sanitary Landfills
Global Partnership on Marine Litter	UNEP	Undated	Marine Litter
Global Waste Management Outlook	UNEP	2015	Planning Systems
Government of India Municipal Solid Waste Management Manual - Chapter 4.5: Municipal Sanitary Landfills	Central Public Health and Environmental Engineering Organisation	2016	Sanitary Landfills
Handbook on Communication and Engagement for Solid Waste Management	Brazilian Association of Public Cleansing and Waste Management Companies and CCAC	2017	Stakeholder Engagement
Improving Solid Waste Disposal in San Cristobal Municipality, Dominican Republic	U.S. EPA	2018	Planning Systems; Dumpsite Management; Sanitary Landfills
International Best Practices Guide for Landfill Gas Energy Projects	Global Methane Initiative	2012	Sanitary Landfills
International Environmental Finance Tools	U.S. EPA	2011	Economic Considerations
International Guidelines for Landfill Evaluation	ISWA	2011	Sanitary Landfills
ISWA Guidelines: Waste to Energy in Low and Middle Income Countries	ISWA	2013	Energy Recovery
ISO Standards for Recycling	International Organization for Standardization	2020	Recycling
Landfill Operational Guidelines. 2nd Edition	ISWA	2010	Sanitary Landfills
Managing and Transforming Waste Streams: A Tool for Communities	U.S. EPA	2017	Prevention and Minimization

Resource	Organization	Year	Relevant Sections
Materials Recovery Facility Toolkit	Asian Development Bank	2013	Recycling
Municipal Finances: A Handbook for Local Governments	Farvacque-Vitkovic and Kopanyi	2014	Economic Considerations
Municipal Solid Waste (MSW) PPPs	The World Bank	2019	Economic Considerations
OrganEcs –Cost Estimating Tool for Managing Source-Separated Organic Waste	U.S. EPA	2016	Organic Waste Management
Overview of Legal Framework for Inclusion of Informal Recyclers in Brazil	Dias	2011	Recycling
Plastics Policy Playbook: Strategies for a Plastic-Free Ocean	Ocean Conservancy	2019	Prevention and Minimization; Informal Sector Recycling; Economic Considerations
Primer for Cities for Accessing Financing for Municipal Solid Waste Projects	ISWA	2017	Economic Considerations
Public Participation Guide	U.S. EPA	2017	Stakeholder Engagement
Recycling and Disposal of Municipal Solid Waste in Low and Middle-Income Countries	UN-Habitat	2011	Recycling
Reducing Food Loss and Waste: Setting a Global Action Agenda	Flanagan et al.	2019	Organic Waste Management
Results-based Financing for Municipal Solid Waste	The World Bank	2014	Economic Considerations
Sanitary Landfill Design and Siting Criteria	Cointreau	2004	Sanitary Landfills
Sector Environmental Guideline Solid Waste	USAID	2018	Approaches; Sanitary Landfills
Solid Waste Management	UNEP	2005	Understanding the Need for Solid Waste Management
Sources: Marine Debris	National Oceanic and Atmospheric Administration	2019	Marine Litter
Sustainable Financing and Policy Models for Municipal Composting	The World Bank	2016	Economic Considerations; Organic Waste Management
Sustainable Materials Management: Non-Hazardous Materials and Waste Management Hierarchy	U.S. EPA	2017	Approaches
Sustainable Materials Management: The Road Ahead	U.S. EPA	2009	Understanding the Need for Solid Waste Management
Technical Guidance on the Operation of Organic Waste Management Treatment Plants	CCAC and ISWA	2016	Organic Waste Management
The Waste Experts: Enabling Conditions for Informal Sector Integration in Solid Waste Management	Gerdes and Gunsilius	2010	Informal Sector Recycling
The Weight of Nations: Material Outflows from Industrial Economies	Matthews et al.	2000	Understanding the Need for Solid Waste Management

Resource	Organization	Year	Relevant Sections
Toolkit: Reducing the Food Wastage Footprint	Food and Agriculture Organization of the United Nations	2013	Prevention and Minimization
Toward Sustainable Municipal Organic Waste Management in South Asia	Asian Development Bank and the Australian Government Aid Program	2011	Organic Waste Management
Training Module: Closing an Open Dumpsite and Shifting from Open Dumping to Controlled Dumping and to Sanitary Land Filling	UNEP	2005	Dumpsite Management
Training: Municipal Solid Waste Management in Developing Countries	Coursera	2019	Dumpsite Management
U.S. EPA Anaerobic Digestion Web Site	U.S. EPA	2020	Organic Waste Management
Using Internal Revenue Streams and External Financing for Solid Waste Management Projects	U.S. EPA and CCAC	2018	Economic Considerations
Waste Atlas (Database of Global Waste Management Sites)	D-WASTE	2020	Dumpsite Management; Sanitary Landfills
Waste Collection: A Report	Kogler	2007	Separation, Collection, and Transportation
Waste to Energy: Considerations for Informed Decision-Making	UNEP	2019	Energy Recovery
Waste Transfer Stations: A Manual for Decision-Making	U.S. EPA	2002	Separation, Collection, and Transportation
Waste-to-Energy Options in Municipal Solid Waste Management: A Guide for Decision Makers in Developing and Emerging Countries	Mutz et al.	2017	Energy Recovery
Webinar: Closure and Rehabilitation of Open Dumps	CCAC	2014	Dumpsite Management
What A Waste 2.0: A Global Snapshot of Solid Waste Management to 2050	Kaza et al.	2018	Understanding the Need for Solid Waste Management ; Recycling
What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. Tackling Increasing Plastic Waste	The World Bank	2019	Recycling
Women in Informal Employment: Globalizing & Organizing	Women in Informal Employment: Globalizing & Organizing	2020	Informal Sector Recycling

Appendix B

Region-Specific Resources for Solid Waste Management

East Asia and the Pacific
Observations of Solid Waste Landfills in Developing Countries: Africa, Asia and Latin America (Johannessen and Boyer 1999)
Solid Waste Management in Pacific Island Countries and Territories (Richards and Haynes 2014)
Challenges and an Implementation Framework for Sustainable Municipal Organic Waste Management Using Biogas Technology in Emerging Asian Countries (IGES 2019)
Latin America and the Caribbean
Waste Management Outlook for Latin America and the Caribbean (UNEP 2018c)
Data Collection Survey on Solid Waste Management Sector in the Central American and Caribbean Region (JICA 2012)
Observations of Solid Waste Landfills in Developing Countries: Africa, Asia and Latin America (Johannessen and Boyer 1999)
Environmental Guidelines for the USAID Latin America and Caribbean Bureau (USAID Undated)
Lixo Fora D'Agua Guidance (in Portuguese and English) (ABRELPE 2020)
Middle East and North Africa
Observations of Solid Waste Landfills in Developing Countries: Africa, Asia and Latin America (Johannessen and Boyer 1999)
South Asia
Observations of Solid Waste Landfills in Developing Countries: Africa, Asia and Latin America (Johannessen and Boyer 1999)
Government of India Municipal Solid Waste Management Manual (CPHEEO 2016)
Composting and Anaerobic Digestion: Promising Technologies for Organic Waste Management (TERI 2020a)
Sub-Saharan Africa
An Overview of Municipal Solid Waste Management in Developing and Developed Economies: Analysis of Practices and Contributions to Urban Flooding in Sub-Saharan Africa (Njoku et al. 2015)
Observations of Solid Waste Landfills in Developing Countries: Africa, Asia and Latin America (Johannessen and Boyer 1999)

Appendix C

Public Engagement/Communication Tools

Tools to Inform the Public					
Tool	**Number of Participants**	**Best Suited for**	**In-Person**	**Virtual**	**Print**
Public meetings Public meetings are held to engage a wide audience in information-sharing and discussion. They can be used to increase awareness or as a starting point for engagement and further public involvement.	Large groups	Smaller cities and cities where stakeholders are willing to attend meetings.	X	X	
Briefings Short presentations given directly to local groups at their existing meetings or locations – such as social and civic clubs – to provide an overview or update on a project.	Generally designed for smaller groups	Reaching out to established groups.	X		
Telephone contacts Calls to specific people or groups of people interested in an issue.	Generally one person at a time	All projects, but require sufficient manpower to answer and/or return calls.		X	
Printed materials Popular forms include fact sheets, flyers, newsletters, brochures, post cards, issue papers, and summary reports.	Unlimited, but printing and mailing costs could be a consideration	Projects with manageable numbers of stakeholders if printing and mailing are to be done. May not be appropriate where literacy is an issue.			X
Websites Worldwide websites provide interested stakeholders with project information, announcements, documents, and opportunities for input or discussion. Web sites allow for the use of a wide variety of media formats, including video.	Unlimited	All projects and audiences where access is available. Literacy issues can be overcome by using voice and video.		X	

Tools to Inform the Public					
Tool	**Number of Participants**	**Best Suited for**	**In-Person**	**Virtual**	**Print**
Information repositories Places to store project information in a centralized public location to provide easy access for residents. Typically, the information stored in a repository is for onsite perusal and review and not to be taken offsite.	Unlimited, but can be geographically constrained by location	Localized projects where access to a physical site is possible. Repositories can also be established online.			X
Information hotlines They provide information in two ways: (1) via live telephone access to project team staff members who can answer questions or provide additional information and assistance, and (2) via a telephone call-in number that provides prerecorded project information.	Unlimited	All projects and audiences, especially those where internet access is an issue.		X	
Press and media Press and media releases aim to get the widest possible coverage for a local issue or proposal through the publication or broadcasting of the information in the release. They may also attempt to elicit further enquiries by the public about the issue.	Unlimited	Larger projects of widespread interest; use of press and media should form part of the overall communications strategy.		X	X
Social media Social media outreach can provide interested stakeholders with project information, announcements, documents, and opportunities for input or discussion. Social media, such as Twitter, WhatsApp, and Facebook, allows for the use of a wide variety of media formats, including video.	Unlimited	Larger projects of widespread interest; social media use should form part of the overall communications strategy.		X	
Tools to Generate and Obtain Public Input					
Interviews Interviews with stakeholders are one-on-one conversations about a specific topic or issue. The primary purpose of these interviews is to obtain project-relevant information and elicit stakeholder reactions and suggestions.	Individual or small group	Learning about individual perspectives on issues.	X	X	

Tools to Inform the Public

Tool	Number of Participants	Best Suited for	In-Person	Virtual	Print
Focus groups A small group discussion with professional leadership. Focus groups are used to find out what issues are of most concern for residents or groups when little or no information is available.	Small groups (15 or fewer)	Exploring attitudes and opinions in depth.	X		
Public meetings/ hearings Public meetings/hearings are held to engage a wide audience in information-sharing and discussion. They can be used to increase awareness or as a starting point for engagement and further public involvement.	Large groups	Presenting information to and receiving comments or feedback from the public.	X		
Public workshops A workshop held by a public agency for the purpose of informing the public and obtaining their input on the development of a regulatory action or control measure by that agency.	Multiple small groups (8–15 in each small group)	Exchanging information and/or problem-solving in small groups.	X		
Appreciative inquiry process A facilitated process to discover past and current practices that inform and inspire participants as they strive to collaboratively create and implement an ideal future.	Varies, but usually involves the "whole system"	Envisioning shared future, not making decisions.	X		
World cafés A meeting process that involves a series of simultaneous conversations around a particular issue or topic. A World Café typically lasts 2–3 hours and consists of numerous table conversations involving 3–5 persons per table. Each table has a "host" who stays at the table during the entire event and keeps the table discussion on track.	Very adaptable, involving multiple simultaneous conversations (4–8 in each small group)	Fostering open discussion of a topic and identifying areas of common ground.	X		

Tool	Number of Participants	Best Suited for	In-Person	Virtual	Print
Tools to Inform the Public					
Charrettes A wide range of interactive tools that embrace existing and emergent media sources as a forum for allowing the public to express opinions and seek to influence decision-making within their area. Electronic democracy can be achieved through older technology, such as television and radio; and newer technologies, such as the internet, cell phones, and electronic polling systems.	Small to medium	Generating comprehensive plans or alternatives.	X		
Electronic democracy A wide range of interactive tools that embrace existing and emergent media sources as a forum for allowing the public to express opinions and seek to influence decision-making within their area. Electronic democracy can be achieved through older technology, such as television and radio; and newer technologies, such as the internet, cell phones, and electronic polling systems.	Unlimited	Enabling the direct participation of a geographically dispersed public at their convenience.		X	
Tools for Consensus Building and Agreement Seeking					
Consensus workshops A type of public meeting that allows stakeholders to be involved in assessing an issue or proposal, and working together to find a common ground and deliver consensus-based input.	Large groups	Smaller, less-controversial decisions or identifying shared values.	X		
Advisory boards A representative group of stakeholders from a particular locality appointed to provide comments and advice on a project or issue that meet regularly over a period of time to develop detailed knowledge of the project and issues; and share their relevant perspectives, ideas, concerns, and interests.	Small groups (25 or fewer)	Long-term and complex processes.	X		

Tools to Inform the Public					
Tool	**Number of Participants**	**Best Suited for**	**In-Person**	**Virtual**	**Print**
Resident juries A representative sample of residents (usually selected in a random or stratified manner) who are briefed in detail on the background and current thinking related to a particular issue or project. The issue they are asked to consider will be one that has an effect across the locality and where a representative and democratic decision-making process is required.	Limited, generally around 12	Decisions that can be organized into clear options.	X		

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October 2020