Clean and low-carbon cities: the relationship between the solid waste management sector and greenhouse gases

TECHNICAL BRIEF

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Municipal solid waste[1] contributes to the generation of GHGs, mainly methane (CH4) and carbon dioxide (CO_2). The amount of GHG emissions from waste is correlated with the quantity of waste and depends on the waste composition and the waste management system in place. Large waste volumes and inadequate waste management systems lead to higher emissions in the atmosphere. In the past many decades, the quantities of waste generated globally have been increasing at an alarming pace while the state of waste management continues to lag in capacity and effectiveness. In a business-as-usual scenario, both waste quantities and emissions from waste will continue to increase. Conversely, achieving reduction in emissions from waste requires, at a minimum, stabilizing or better reducing the quantities of generated waste along with a drastic improvement in how it is managed.

This short briefing note provides a quick summary on the relationship between municipal solid waste and GHGs, and a path for curbing emissions from waste.

GHG emissions from waste are large and growing. Estimates stand at 1.6 billion tonnes (2016) – about 5 percent of all global CO_2-equivalent (CO_2e) emissions[2] and up to 20 percent of global methane stem from human activity[3]. These are direct emissions resulting mainly from organic waste decomposing in anaerobic conditions in dumps and landfills and are emitted to the atmosphere in the absence of proper landfill gas management system. While several short-lived climate pollutants[4] are generated by mismanagement of waste, methane and black carbon[5] are the most significant ones. Some scholars[6] have cautioned that the estimates above neglect the contribution of black carbon. They estimate there could be another 2-10% of global CO_2e emissions generated from black carbon when waste is openly burned.

Direct emissions from waste are projected to increase to 2.6 billion tonnes CO_2e by 2050[7] in a business-as-usual scenario and much of this contribution will be from methane—one of the most powerful drivers of climate change among the short-lived substances. Compared to other prime sources of anthropogenic methane emissions, namely the oil and gas sector and agriculture, the largest projected increases in methane generation are from waste, driven by population growth and increase in waste generation per capita.[8] The mitigation potential from the waste sector is therefore expected to continue to increase in the future.[9]

1 Municipal waste is defined as waste collected and treated by or for municipalities. It covers waste from households, including bulky waste, similar waste from commerce and trade, office buildings, institutions and small businesses, as well as yard and garden waste, street sweepings, the contents of litter containers, and market cleansing waste if managed as household waste. The definition excludes waste from municipal sewage networks and treatment, as well as waste from construction and demolition activities (definition by OECD).

2 What a Waste 2.0, World Bank, 2018

3 Global Methane Assessment, CCAC and UNEP, 2021. Estimated methane emissions from landfills and waste including wastewater - 68 million tonnes/year, 2017

4 Short-lived climate pollutants are in the air for a shorter period of time than CO2 but have a greater warming potential. (Climate and Clean Air Coalition, https://www.ccacoalition.org/en/content/short-lived-climate-pollutants-slcps)

5 Black carbon is part of fine particulate air pollution (PM2.5) with a warming impact on climate 460-1,500 times stronger than CO2 per unit of mass. (https://www.ccacoalition.org/en/slcps/black-carbon)

6 David Wilson, Better Waste and Resource Management Can Contribute Significantly to Climate Mitigation, 2021 (https://www.iswa.org/blog/better-waste-resource-management-can-contribute-significantly-to-climate-mitigation/?v=7516fd43adaa#_ednref11), Natalia Reyna-Bensusan, David C.Wilson, Pamela M. Davy, Gary W.Fuller, Geoff D. Fowler and Stephen R. Smith, 2019. Experimental measurements of black carbon emission factors to estimate the global impact of uncontrolled burning of waste, 2019. Atmospheric Environment, 213, 629-639.

7 What a Waste 2.0, World Bank 2018

8 Global Methane Assessment, CCAC and UNEP, 2021

9 Ibid

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Beyond direct emissions, GHGs are emitted in the process of manufacturing materials and products which could be recycled, reused or repurposed, and more generally prevented, if the waste management system supports the capture of such materials and if products are designed and manufactured in ways that allow for reuse or recycling. Indirect savings in GHG emissions occur when new virgin material whose production is associated with higher energy intensity is replaced with recyclate. For example, according to Ellen MacArthur Foundation, steel recycling uses 10-15 percent of the energy required in the production of primary steel[10] with significantly lower associated emissions while recycling 1 tonne of plastics reduces emissions by 1.1-3.0 tonnes of CO_2 compared to producing the same tonne of plastics from virgin fossil feedstock[11].

The substantial abatement potential, both of direct emissions and indirect savings, is predicated on the ability of waste management systems to manage organic wastes effectively and capture and redirect the residual waste material towards further utilization in close-looped economies. However, a projected increase in waste quantities generated globally will continue to strain the already underperforming waste management systems. It will take a significant improvement to the status quo for a cumulative reduction in GHG emissions from waste.

Waste quantities and waste generation globally have been increasing over time and are expected to continue to grow. According to available data, waste production will be 73 percent higher in 2050 than in 2020 in a business-as-usual scenario[12]. Some scholars expect that 'peak waste'—that is when waste generation per capita globally is decoupled from economic growth and will start to trend down—will not be reached until the end of the century[13]. While decoupling has been observed in some higher income countries where waste production is beginning to curve down[14], waste generation continues to climb in the vast majority of countries and regions.

Going forward, the largest increase in generated waste volumes is expected to be in middle-income countries where waste generation is projected to nearly double in the next three decades. In low-income countries (LICs) waste generation is expected to nearly triple while in high-income countries (HICs) it is expected to increase 18% (see Figure 1). Across all income groups, the increase will be driven by high levels of growth in both economic activity and/or population. Urbanization will additionally contribute to this process as higher urban consumption patterns replace rural ones.

It is worth emphasizing that the recent decisive shift in policy frameworks and corresponding initiatives towards resource efficiency and improved resource utilization as part of a larger policy agenda towards circular economy signals willingness to shift towards a conserver society where waste prevention, minimization, and circularity take effect. If a new social contract on consumption patterns and waste generation and handling with citizens and populations-at-large is accomplished, and is endorsed and supported by economic players, industries and manufacturers, waste generation rate may slow down and 'peak waste' might be achieved earlier than projected.

Effective waste management systems can reduce GHG emissions from waste. How the world manages its waste today is concerning (see Figure 2). A whopping 93 percent of the waste in LICs is improperly dumped. 66 percent and 30 percent of the waste in lower-middle-income countries (LMICs) and upper-middle-income countries (UMICs), respectively, is also dumped in uncontrolled sites. HICs continue to landfill a third or so of their waste while UMICs landfill more than half, recycle and compost less than 10 percent.

The impacts of such practices are dire and go beyond GHG emissions. At the local level, widespread pollution reduces quality of life through environmental, social, and health consequences that affect the poor disproportionately.

10 The new plastics economy: rethinking the future of plastics, Ellen MacArthur Foundation, 2016
11 Ibid and Completing the picture: how the circular economy tackles climate change, Ellen MacArthur Foundation, 2019
12 Kaza, S., Shrikanth S. and Chaudhary, S., More Growth Less Garbage, World Bank, 2021
13 Hoornweg, Bhada-Tata, Kennedy, Peak Waste: When will it likely occur?, 2015, and updated calculations with data from What a Waste 2.0 (2018)
14 Kaza, S., Shrikanth S. and Chaudhary, S., More Growth Less Garbage, World Bank, 2021

Figure 1: Projected Total Waste Generation by Income Group (More Growth Less Garbage, World Bank, 2021)

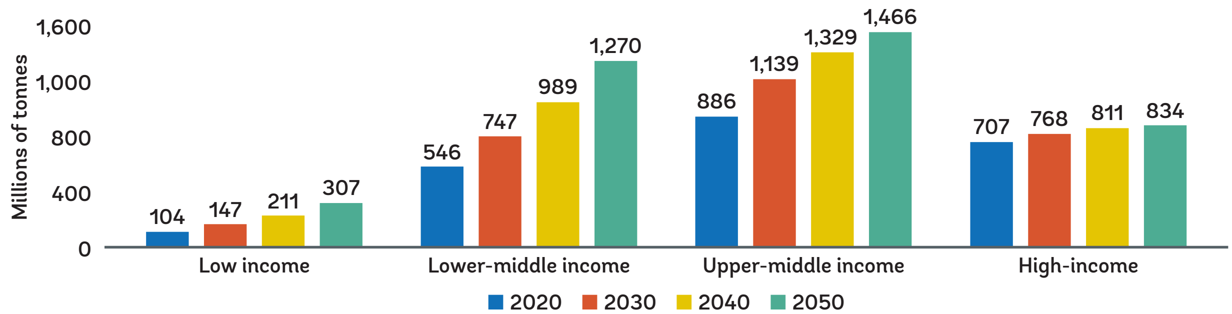

Figure 2: Disposal method by income and region (What a Waste 2.0, World Bank, 2018)

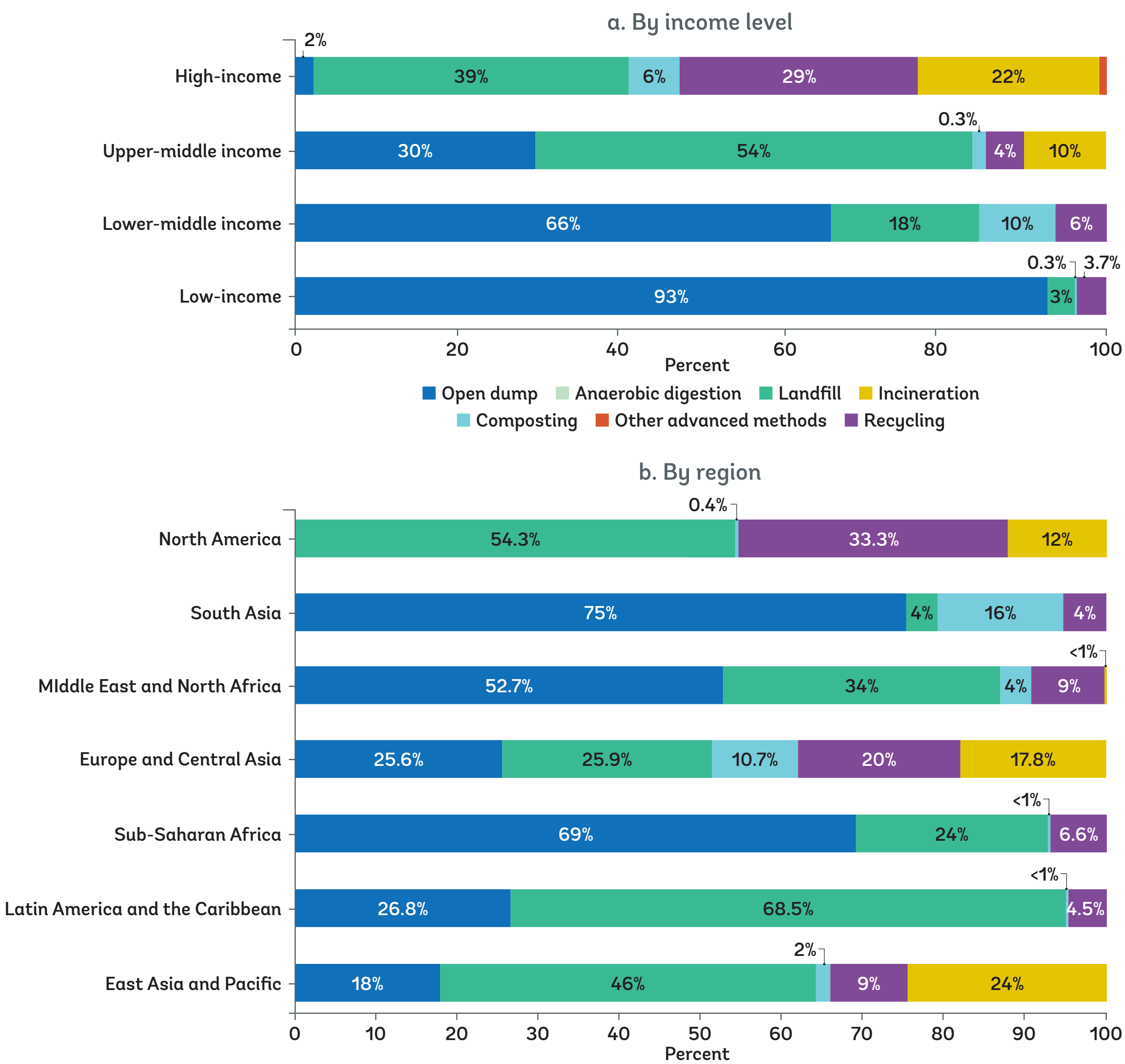

Photo: © Roncivil | Dreamstime.com

Open burning of waste is a major contributor to local air pollution. Uncollected and dumped waste exacerbates the effects of flooding especially in low-lying urban areas with high precipitation while unprotected disposal sites along riverbeds and coastlines are vulnerable to sea-level rise and secondary pollution. Improperly stored waste acts as a breeding ground for vector-borne zoonotic diseases. Globally, beyond climate impacts, municipal solid waste is the major source of marine pollution. Over 80 percent of ocean plastics comes from unmanaged or poorly managed municipal solid waste on land.[15] Three-quarters of that quantity is found to come from uncollected waste with the remaining quarter leaking from within the waste management system due to poor controls and secondary pollution, such as unauthorized dumping of collected waste.

The situation today, most notably the very high share of dumping, points to a significant potential to improve the status quo. Reducing direct emissions from dumping and landfilling without a well-performing landfill gas management system should be prioritized. As flagged by the Global Methane Assessment[16] reducing methane is the fastest way to slow global warming. Given the minimal remaining carbon budget to stay within the 1.5°C increase Paris Agreement goal, the Global Methane Pledge[17] commits participating nations to focus on curbing methane emissions that have a much shorter lifespan than CO_2. In the waste sector, countries relying on disposing waste on land with large-scale uncontrolled dumping are at the forefront of such actions.

To exemplify the potential of emission reductions related to dumping, modeling was carried out using More Growth Less Garbage, What a Waste 2.0 and the CURB tool[18]. Two scenarios were developed per country group—for LICs, LMICs and UMICs: the *low* scenario is where dumping is reduced from its current levels by 5, 15, and 25 percentage points in three 5-year increments; the reductions in volumes of waste dumped were then redirected under the model to other treatment methods within the waste hierarchy. Resulting emissions for the management of all waste were then calculated and compared to the business-as-usual scenario showing the emissions abatement potential. A *higher* scenario assumes 5, 25, and 50 percentage points reduction in dumping and follows a similar approach as described above. It can be seen in Figure 3 that given the rapid increase in waste quantities, under the *low* scenario, emissions in LICs will continue to increase while in LMICs emissions will remain almost equivalent to current levels. Only under the *higher* scenario we start to see more tangible reductions compared to current emission levels. The modelling demonstrates that to have a sizeable cumulative reduction of direct GHG emissions from the municipal waste sector, bold interventions will be needed to reduce and ultimately eliminate dumping.

At a country or state level, efforts to eliminate large-scale dumping would normally start with the adoption of a national/state dumpsite closure and replacement program. Such a program would be based on an inventory of existing sites, a closure strategy for phasing out unmanaged sites within a specified time period, and an operational plan for providing grant funding for national priority projects outlined in the closure and replacement program. The availability of grant funds could be an incentive for municipalities to collaborate with their neighbors in forming, where needed, inter-municipal (or similar) entities and for those entities to apply for funding support for the development of environmentally compliant waste treatment and disposal facilities compliant with strategic objectives and program conditions. In parallel, waste collection must increase if base levels are low, and corresponding compliance enforcement for waste generators and handlers must be put in place to ensure that dumping does not reoccur.

15 Stemming the Tide: land-based strategies for a plastic free ocean, Ocean Conservancy and McKinsey Center for Business and Environment, 2015
16 Global Methane Assessment, CCAC and UNEP, 2021
17 See https://www.globalmethanepledge.org/
18 See https://www.worldbank.org/en/topic/urbandevelopment/brief/the-curb-tool-climate-action-for-urban-sustainability. CURB uses the methane commitment method which is one of two accepted methodologies under the Global Protocol for Community-Scale Emissions to estimate emissions. The methane commitment method assumes methane is produced immediately based on recent data versus the first order decay model which accounts for historical waste managed. As a result, the methane commitment model overstates results. Less data is required for the methane commitment and is utilized in CURB due to the data scarce nature of the sector to obtain approximate emissions implications.

Figure 3: Demonstration scenarios for CO2e emissions due to reduction in dumping

Photo: © Belish

Note regarding Figure 3: *The modelling is intended for indicative purposes only to exemplify the potential of emission reductions related to reduced dumping. The assumptions on waste handling and treatment mix under the two scenarios are listed below. The baseline scenario is based on data in What a Waste 2.0 (2018) which is based on publicly available sources and may not in all cases account for recyclables handled via the informal sector that have not entered the public waste stream. Due to many uncertainties that remain with regards to future treatment mix and the large number of countries in each country-income group, the results should be viewed in terms of trends rather than emission volumes.*

As shown in the graphs, in LICs, the low scenario leads to CO2e reduction of 9.4 million tonnes (MT) in 2025 (10.3%), 18.8 MT in 2030 (17.4%) and 32.6 MT in 2035 (25.3%), whereas a more ambitions higher scenario brings 27.3 MT in 2030 (25.2%) and 65.5 MT in 2035 (50.7%). In LMICs, the low scenario leads to reduction of 59.6 million tonnes (MT) in 2025 (11.8%), 151.5 MT in 2030 (25.6%) and 273.7 MT in 2035 (40.1%), whereas a more ambitious higher scenario brings 263.3 MT in 2030 (44.4%) and 341.2 MT in 2035 (50%). In UMICs, the low scenario leads to CO2e reduction of 105.8 million tonnes (MT) in 2025 (15.1%), 315.1 MT in 2030 (39.7%) and 470.9 MT in 2035 (54.8%), and 406.3 MT in 2030 (51.2%) and 675.5 MT in 2035 (78.6%) under the higher scenario.

Assumptions under the low scenario:

- *For LICs:*
  - *baseline scenario: 93% dumping, 3% landfilling, 3.7% recycling and 0.3% composting;*
  - *first 5-year increment: 88% dumping, 7% landfilling, 4% recycling, 1% composting;*
  - *second 5-year increment: 78% dumping, 14% landfilling, 6% recycling, 2% composting;*
  - *third 5-year increment: 68% dumping, 20% landfilling, 10% recycling, 2% composting.*
- *For LMICs:*
  - *baseline scenario: 66% dumping, 18% landfilling, 6% recycling and 10% composting;*
  - *first 5-year increment: 61% dumping, 22% landfilling, 7% recycling, 10% composting;*
  - *second 5-year increment: 51% dumping, 30% landfilling, 9% recycling, 10% composting;*
  - *third 5-year increment: 41% dumping, 38% landfilling, 11% recycling, 10% composting.*
- *For UMICs:*
  - *baseline scenario: 30% dumping, 54% landfilling, 4% recycling, 2% composting and 10% incineration;*
  - *first 5-year increment: 25% dumping, 58% landfilling, 5% recycling, 2% composting and 10% incineration;*
  - *second 5-year increment: 15% dumping, 60% landfilling, 8% recycling, 4% composting and 13% incineration;*
  - *third 5-year increment: 5% dumping, 60% landfilling, 14% recycling, 6% composting and 15% incineration.*

Assumptions under the higher scenario:

- *For LICs:*
  - *baseline scenario: 93% dumping, 3% landfilling, 3.7% recycling and 0.3% composting;*
  - *first 5-year increment: 88% dumping, 7% landfilling, 4% recycling, 1% composting;*
  - *second 5-year increment: 68% dumping, 20% landfilling, 10% recycling, 2% composting;*
  - *third 5-year increment: 43% dumping, 35% landfilling, 12% recycling, 10% composting.*
- *For LMICs:*
  - *baseline scenario: 66% dumping, 18% landfilling, 6% recycling and 10% composting;*
  - *first 5-year increment: 61% dumping, 22% landfilling, 7% recycling, 10% composting;*
  - *second 5-year increment: 41% dumping, 38% landfilling, 11% recycling, 10% composting;*
  - *third 5-year increment: 16% dumping, 55% landfilling, 17% recycling, 12% composting.*
- *For UMICs:*
  - *baseline scenario: 30% dumping, 54% landfilling, 4% recycling, 2% composting and 10% incineration;*
  - *first 5-year increment: 25% dumping, 58% landfilling, 5% recycling, 2% composting and 10% incineration;*
  - *second 5-year increment: 5% dumping, 60% landfilling, 14% recycling, 6% composting and 15% incineration;*
  - *third 5-year increment: 0% dumping, 35% landfilling, 35% recycling, 15% composting and 15% incineration.*

Curbing direct emissions by reducing and eliminating dumping will also go a long way to support recycling, reuse and therefore indirect savings. Where large-scale dumping is eliminated, waste generators are placed to operate within the *waste hierarchy*[19] and governments can more effectively employ economic instruments to steer the sector towards landfill diversion, recovery, recycling, and circular loops. Conversely, if large-scale dumping remains a plausible option for waste generators, other environmentally superior treatment options with higher financial costs could be less attractive to many. Eliminating large-scale dumping as an option to dispose waste is hence foundational to allow the sector to sustainably scale and transition up the waste hierarchy. This is an important point to reflect in national plans aimed at transitioning up the waste hierarchy and towards a circular economy.

Eliminating dumping and installing functional landfill gas management systems will go a long way to reduce emissions from waste. However, it may not be sufficient on its own. Organic waste should ideally be diverted and treated separately. Organic waste forms a large part of the waste. In HICs it is about 30 percent of the generated waste; in all other country income groups—it exceeds 50 percent.[20] A literature review of life-cycle assessments comparing the GHG footprint of different treatment options for organic waste found that aerobic composting and anaerobic digestion are both environmentally preferable in terms of climate change impacts to either waste-to-energy or landfill gas to energy[21]. Separation at source and diversion of organic waste also reduce the contamination of residual material that could be recycled, improving its reselling value and the economics of recycling systems. It also improves the calorific value of residual comingled waste that is not suitable for recycling but could be used for energy and heat recovery.

Achieving this level of sophistication of the waste management system—with separate collection of organics and recyclables, advanced treatment at scale, high degree of recycling, productive utilization of generated emissions is typical for many HICs. Their experiences demonstrate that progress has not been achieved in a single step but has required concentrated efforts and resources over several decades focused on evolving sector governance architecture, citizen participation, strict compliance and enforcement, and the availability and predictability of financing.[22] Collectively these measures in HICs have worked to make every next level within the *waste hierarchy* more financially and economically attractive, having the sector transition away from landfilling towards more preferable waste management options.

Low- and medium-income countries will need to study these experiences and lessons learned and move forward rapidly through the adoption of modern systems for waste management that are also sustainable. Presently, in many, if not most, developing countries, a significant disconnect is observed between national ambition for the sector as recorded in national strategies and actual performance by local governments responsible for service delivery. Central authorities are seen to regard solid waste management as a strictly local function and beyond their mandate. Line ministries often do not see it as being either their role or practical for them to provide the guidance, support and resources needed by local authorities to implement national policy. Yet, the primary responsibility to set the overall institutional, policy, and legislative framework for waste management belongs with central governments. The primary responsibility for providing waste services belongs with local authorities that often remain fiscally constrained with many competing priorities beyond waste and limited ability

[19] The *waste hierarchy* principle 'defines a preferred order of waste management practice, subject to technical feasibility, affordability and financial sustainability constraints: prevention, (preparing for) reuse, recycling, recovery and, as the least preferred option, disposal (which includes landfilling and incineration without energy recovery)', based on Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives, EU Waste Framework Directive

[20] What a Waste 2.0, World Bank 2018

[21] Jeffrey Morris, H. Scott Matthews, Clarissa Morawski, Review and meta-analysis of 82 studies on end-of-life management methods for source separated organics, Waste Management, 2012. Also noted is that no single end of life management method consistently topped all other management options across all environmental impacts however dumping and open burning generate the highest tonnes CO2e per unit of waste.

[22] Bridging the Gap in Solid Waste Management: Governance Requirements for Results, World Bank, 2021

to deliver adequate service. In comparison, in countries that have successfully upgraded their waste sector, the process has typically started with a broad-based recognition that waste management is a core public service deserving the same level of political and other support as other public services, including water supply, wastewater treatment, and electricity supply. Equally important has been the recognition that the waste sector is not a compilation of waste management systems of individual cities or towns but a geographically integrated system with strong interconnections between levels of government; and where local governments responsible for service delivery are guided, empowered, influenced, incentivized and very importantly resourced to perform at the desired level.[23]

[23] Ibid

In conclusion, it could be argued that given the many concerning impacts of inadequate waste management and the trajectory of the sector, a business-as-usual scenario is not sustainable. Today, the mitigation potential of the waste sector is clearly an imminent driver but local and global pollution of air, water, and soil and associated impacts on health and the economy, and the continuous wastage of resources through open-loop waste systems are each a sufficient justification to prioritize the sector as a local and a global essential public good. Without doubt, intensive efforts and resources will be required for cumulative improvements to reduce waste generation, achieve responsible and effective waste management, transition to a conserver society and build more sustainable circular practices. The preponderance of the evidence is that this presents an urgent, forefront task for the world, its governments, and the global development community.

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