ZERO WASTE TO

ZERO EMISSIONS

How reducing waste is a climate gamechanger

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gaia

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Executive summary

This report is organized around the three overarching positive impacts of incorporating zero waste systems into current waste management methods: climate mitigation, climate adaptation, and additional societal benefits (also referred to as co-benefits). The final chapter of the report offers case studies that model the effects of zero waste strategies in eight different cities, demonstrating that zero waste is a powerful mitigation strategy that is highly adaptable to different needs and circumstances. Cities around the world have already implemented zero waste systems; with these eight case studies, this report offers a new quantitative assessment of the mitigation benefits of such programs.

As the climate crisis deepens, urgent action on all fronts is required to both eliminate greenhouse gas (GHG) emissions and adapt to a rapidly changing climate. The waste sector offers a prime opportunity for cities to take action that will dramatically reduce emissions, strengthen resilience, and provide substantial public health and economic benefits. The waste sector is the third largest source of anthropogenic methane emissions, whose reduction will deliver rapid benefits through avoided warming. In fact, good waste management practices can reduce emissions in other sectors, delivering more than 100% emissions reductions. Simultaneously, this approach, known as zero waste, can reduce flooding, deter disease transmission, improve soil health, and deliver economic opportunities. This report explains how zero waste is an essential part of any climate plan.

Seventy percent of global greenhouse emissions come from the material economy, from extraction through disposal. In national inventories, these emissions are tallied in the industrial, agricultural, transportation, and energy sectors, as well as the waste sector. Yet curbing waste generation and implementing better waste management strategies avoids emissions throughout the lifecycle of material goods—from extraction to end of life. The mitigation potential of the waste management sector is therefore largely underestimated.

Zero waste systems are versatile strategies that aim to continually reduce waste through source reduction, separate collection, composting, and recycling. Over 550 municipalities around the world are already implementing zero waste, in a wide range of economic, social, climatic, and legal contexts. Furthermore, these systems are cost-effective to implement and produce fast results.

Climate mitigation

Zero waste systems contribute to greenhouse gas emissions reductions in three ways: **source reduction and separate collection and treatment of organic waste** avoids landfill methane emissions; **land application of compost** or digestate enhances the carbon uptake of the soil; **and source reduction and recycling of all municipal waste streams reduces "upstream"** emissions from natural resource extraction, manufacturing, and transport;

Key takeaway 1

Composting is a climate game changer.

- Separate collection of different waste streams is critical to avoid cross-contamination; the most readily implementable treatment option for organic waste is composting.
- Source-separated collection and treatment of organics can reduce methane emissions from landfills by 62%, even with moderate ambition.
- Mechanical recovery and biological treatment of residual waste and biologically active landfill cover are good complementary measures to source separated organic waste collection; in tandem, these strategies can reduce methane emissions by an average of 95%.

Key takeaway 2

The zero waste model can transform the waste sector into a net negative source of GHG emissions.

- Introducing better waste management policies such as waste separation, recycling, and composting could cut total emissions from the waste sector by 84% or more than 1.4 billion tonnes, equivalent to the annual emissions of 300 million cars - or taking all motor vehicles in the U.S. off the road for a year.
- Separate collection and treatment of organic waste is key to deep cuts in waste-sector GHG emissions.
- Aggressive recycling programs reduce emissions in mining, forestry, manufacturing, and energy. Increased recycling would reduce annual GHG emissions in the waste sector by 35% in Detroit, 30% in Sao Paulo, and 21% in Lviv by 2030
- Combined, these two approaches can produce deeper emissions reductions than waste sector emissions. Detroit, São Paulo, and Seoul would all achieve net-negative emissions under the 'road-to-zero-waste' scenarios.
- This is true even for relatively modest programs; full implementation of zero waste would produce even greater emissions reductions.

Key takeaway 3

Source reduction of waste is the best way to reduce GHG emissions, especially for food and plastic (better than recycling).

- Source reduction is a critical strategy for addressing food waste, which currently comprises one-third of all food production and is responsible for 10% of global GHG emissions.
- Other strategies for source reduction include restrictions on the production and distribution of single-use items and packaging.
- Source reduction is especially important for plastic, most of which is not recyclable and whose production is doubling every 20 years.

Key takeaway 4

Energy recovery is not an effective mitigation strategy

- Landfill gas capture is unreliable, allowing large quantities of fugitive methane emissions to escape.
- Incineration is a major source of GHG emissions: each tonne of plastic burned results in the release of 1.43 tonnes of CO_2, even after energy recovery.
- Insufficient energy is recovered to offset the carbon footprint of these technologies.

Climate adaptation

Zero waste systems help cities build resilience against the increasingly frequent extreme weather events and health hazards brought by climate change. Poor waste collection and management are among the factors that leave cities particularly exposed to these events. Zero waste systems help cities become more resilient by: **mitigating floods, reducing disease transmission**, and **improving soil quality**.

Key takeaway 1

Bans on single-use plastic (SUP) are necessary as plastic waste exacerbates flooding.

- Plastic bans and universal collection systems are key to flood prevention as improperly managed waste— especially plastic bags —lead to clogged drainage systems.
- After tragic flood events, many cities have successfully and swiftly adopted plastic bans.

Key takeaway 2

Banning SUPs and better waste collection will keep disease vectors at bay.

- Uncollected waste, especially plastic, creates habitat (e.g., stagnant water) for disease vectors, while food waste provides a food supply for vermin.
- Reducing waste through bans on SUPs and minimizing discarded food can help to interrupt the chain of disease transmission.

Key takeaway 3

Composting does wonders to improve soil resilience.

- Land application of compost helps nutrient-deficient soil by increasing nutrient storage capacity, biochemical properties, crop production, and water retention.
- Better soil quality prevents floods, mudslides, and loss of food crops.

Additional benefits

Well-implemented zero waste strategies benefit societies in ways that go beyond their ability to curb the impacts of climate change: they improve many of the most fundamental ways in which society functions– through associated **environmental, economic, social**, and **political and institutional benefits**. These additional benefits include improving public health, reducing environmental pollution, incentivizing job creation, supporting community development, and addressing inequalities and societal injustices. Furthermore, waste solutions at the top of the waste hierarchy not only have the greatest additional benefits, but also score highest on emissions reductions.

Key takeaway 1

Zero waste systems do more for our health and the environment than lower GHG emissions. Zero waste systems:

- Lower the risk of cancer and illnesses associated with the spread of toxic ash from incinerators and landfills by rendering them redundant;
- Save natural resources by decreasing the need and demand for virgin materials;
- Protect ecosystem health by decreasing plastic pollution, which currently affects all living organisms;

Key takeaway 2

Zero waste systems contribute to a thriving economy. Zero waste systems:

- Are more economical than traditional waste management strategies;
- Offer more and better employment opportunities than traditional waste management jobs;
- Spur business development: bans of single-use plastic have opened the door to innovative businesses.

Key takeaway 3

Zero waste systems provide a wide range of social benefits. Zero waste systems:

- Reduce poverty and inequality through the inclusion of informal waste pickers; .
- Improve public health by decreasing the amount of toxic chemicals in the environment;
- Improve food and water security via the application of compost and biodigestate, which support food and water ecosystems;
- Reduce environmental stressors associated with waste disposal facilities.

Key takeaway 4

Zero waste systems strengthen the quality of governance itself

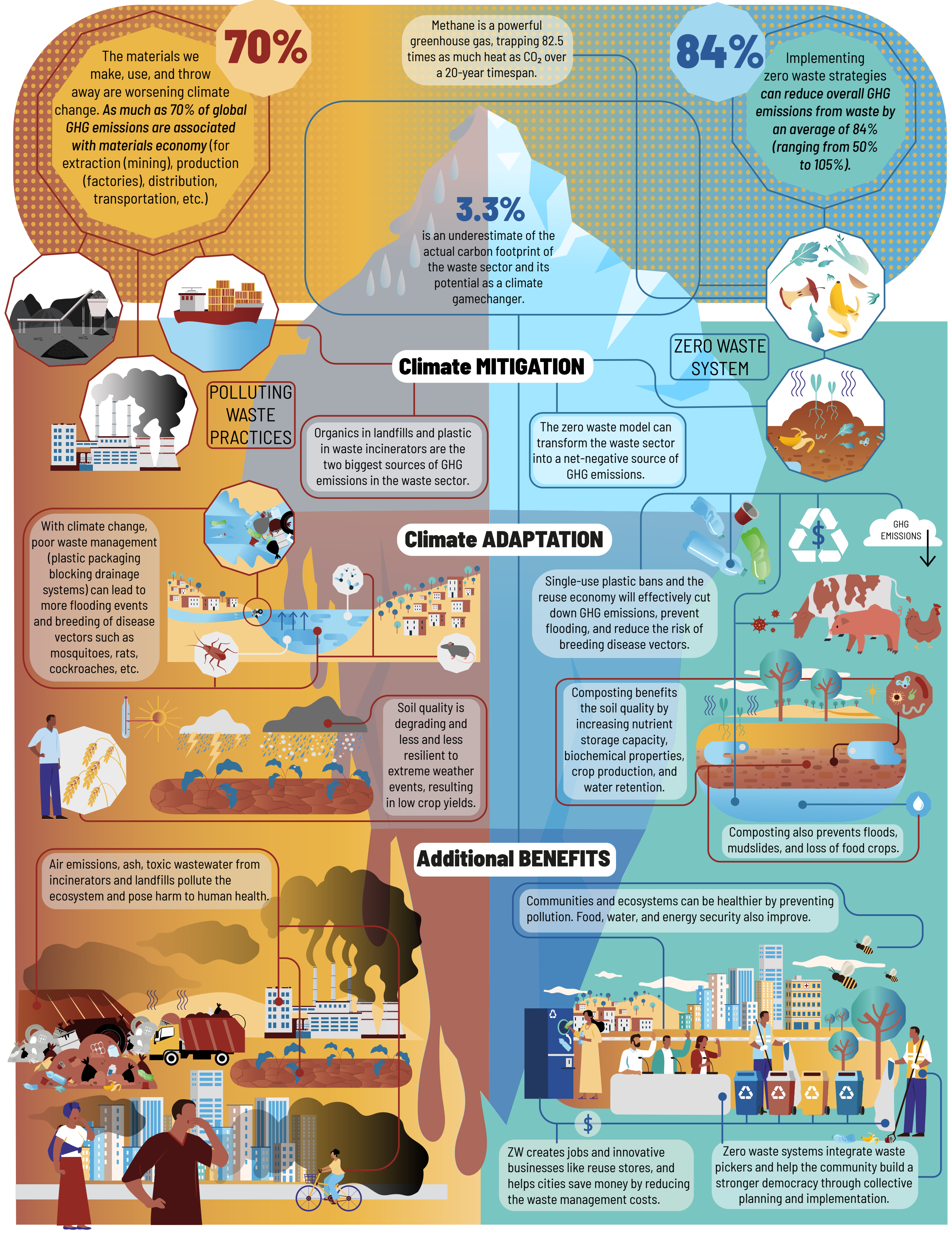
- Bringing together a wide range of stakeholders, zero waste systems are more collaborative and demonstrate high performance rates as a result.

Case Studies

Modeling a business-as-usual versus a road-to-zero-waste scenario for eight cities revealed several commonalities regarding the efficiency and impact of zero waste systems. Source-separated collection and treatment (usually through composting) of organic waste is key to deep emissions reductions, as landfill methane is the primary source of GHG emissions in the waste stream in every city but Seoul. This is also the only effective method to fully address these emissions, and it is relatively easy and inexpensive to implement. Recycling is also key, as increased recycling reduces emissions, and can, in some cases, be enough to make a city's waste sector net negative. While source reduction strategies are underutilized across the board, all zero waste policy and programs, even when incompletely implemented, lead to major mitigation benefits everywhere. The 'road to zero waste' scenarios modeled here are conservative, realistic scenarios; many cities have already exceeded the benchmarks in these scenarios, and the results are thus indicative of moderately ambitious programs. Deeper emissions cuts can be expected from more ambitious zero waste implementation.

ZERO WASTE TO ZERO EMISSIONS

How reducing waste is a climate gamechanger



@John McConnico/AP

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Introduction

As the urgency of global efforts to curtail greenhouse gas (GHG) emissions and the effects of climate change escalates, the waste management sector remains an underutilized opportunity for climate action by municipalities in countries everywhere. The mitigation potential of waste management is greater than the sector's own emissions, as waste reduction and material recovery strategies enable cities to avoid emissions associated with natural resource extraction and production, as well as the end of life of material goods; for example, an analysis jointly conducted by the United Nations Environment Programme and International Solid Waste Association recognized the waste sector's potential of achieving a 20% reduction in global GHG emissions[1]. Our current waste crisis is itself threatening the health and wellbeing of humanity and the planet, and global waste generation is expected to increase by 73% in 2050.[2] The good news is that addressing our waste problem is a direct line of action against the climate crisis.

Zero waste systems offer alternative solutions to traditional waste management practices with far-reaching benefits. Zero waste, as defined by the Zero Waste International Alliance and adopted by GAIA, "is the conservation of all resources by means of responsible production, consumption, reuse, and recovery of products, packaging, and materials without burning, and with no discharges to land, water, or air that threaten the environment or human health."[3] The aim of zero waste is to continually reduce waste through a range of strategies including source reduction, separate collection, composting, and recycling.

This report is the first of its kind to quantify the climate impacts of better waste management with case studies on eight cities, each in a different part of the world. This report also examines the ways in which zero waste systems not only mitigate GHG emissions, but also help cities reduce their vulnerability to the impacts of climate change and create overall healthier societies. Devastating signs of the climate crisis—including increased flooding, outbreaks of vector-borne diseases, and degrading quality of soil—are already harsh realities faced by many countries across the globe. Often, the countries suffering most from such effects are the ones least responsible for causing climate change, and the severity of the consequences are becoming increasingly apparent as the climate crisis accelerates.

Cities have a unique opportunity to tackle climate change through the waste sector. While many other sectors are the responsibility of national or provincial-level governments, waste management is almost always the exclusive responsibility of local governments. Waste management is also typically the single largest budget item in municipal budgets, and even so, many cities struggle to simply collect the existing waste. There is thus a need for improved and economical waste management approaches that simultaneously address climate change[4]. Zero waste offers cities a leadership opportunity on climate action, while managing known and new risks. This will help build both long-term resilience against climate change, and provide much needed short-term results, all with a relatively small budget.

> *Zero waste systems are no longer a novel approach: they are being implemented by over 550 municipalities around the world,*

in very diverse contexts, including big and small cities, towns, islands, and touristic destinations—whether wealthy or impoverished. Beyond positive climate action, zero waste systems improve many of the fundamental ways societies function. Tacloban City, Philippines, for instance, went from servicing 30% of households with waste collection to 100% in two years of implementation of a zero waste system, reducing the waste sent to landfills by 31%, and saving 27% of waste management costs.[5]

> *Ljubljana, Slovenia, tripled jobs in the waste sector and saved costs while doubling recycling rates in eight years and reducing waste-to-landfill by 95% in 14 years through door-to-door collection combined with a pay-as-you-throw system.*[6]

An increasing number of local governments consider zero waste a powerful climate action strategy. As a sector that usually lies entirely within local control and consumes an enormous portion of city budgets, solid waste management is a prime area in which municipalities can apply zero waste strategies to reduce their climate impact and build more just and resilient cities.

Zero waste as a speedy solution

To tackle the climate crisis, rapid solutions are essential. In contrast with major infrastructure projects such as incinerators and landfills, which take many years to site, permit, and build, zero waste implementation is extremely rapid. This is particularly true for the crucial element of source separation, which relies on high levels of public cooperation. For example, Prelog, Croatia, tripled source separation in five years.[7] In Dar es Salaam, Tanzania, the zero waste system implemented by Nipe Fagio to engage 32,000 people achieved 95% compliance in source separation and reduced waste disposal by 75% in just two years.[8] In San Fernando, Philippines, waste diversion increased from 12% to 80.69% in six years after implementing a zero waste system.[9] In Besançon, France, the implementation of a pay-as-you-throw system and decentralized composting reduced overall waste generation by 13% in seven years.[10] In Santa Juana, Chile, organic waste sent to landfill was reduced by 35% in the first four months of implementation of a zero waste-oriented program.[11] Sălacea, Romania, went from almost zero recycling to 40% in the first three months of zero waste implementation.[12] Capannori achieved a 82% separate collection rate in six years[13] and Parma, Italy, increased separate collection from 48.5% to 81% in seven years.[14] In Usurbil, Basque region, Spain, separate collection went from 28% to 80% in just two years.[15] These and other examples testify to the speed with which zero waste can take effect.

@Grisha Levit

2.

Zero waste and climate mitigation

Chapter summary

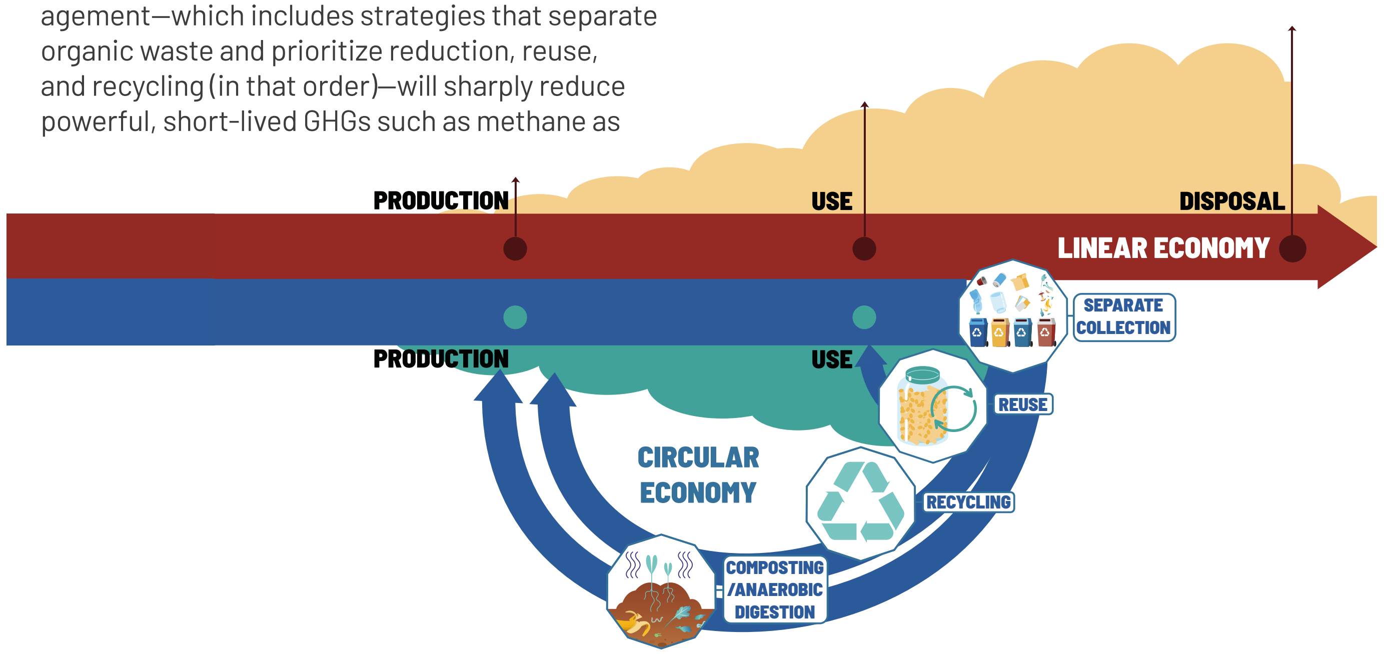
- The waste sector is the third largest source of methane emissions, a powerful GHG that traps 82.5 times as much heat as CO_2 over a 20-year timespan. Organic waste in landfills is a major source of methane emissions, and proper organic waste management can dramatically lower these emissions.
  - Source-separated collection and treatment of organics can reduce methane emissions from landfills by 62%, even with moderate ambition.
  - Separate collection of organic waste, composting, mechanical recovery and biological treatment of residual waste, and biologically active landfill cover can reduce methane emissions by an average of 95**%**. Other treatment methods, such as animal feed and anaerobic digestion, may be appropriate in some circumstances.
- The mitigation potential of zero waste systems in the waste sector is largely underestimated and presents an underutilized opportunity to mitigate climate change.
  - Reducing upstream emissions from natural resource extraction, manufacturing, and transport by preventing waste and decreasing the demand for raw materials through reuse and recycling.
  - Ending waste incineration and open burning eliminate their direct emissions of fossil and biogenic CO_2.
  - Land application of compost or digestate can enhance carbon uptake of soils.
- A comprehensive zero waste strategy can reduce more emissions than the waste sector produces, resulting in a "net negative" sector.
- Plastic, a fossil fuel product and uniquely problematic material, has an enormous carbon footprint, two-thirds of which is in the production phase. As recycling plastic has critical limitations, forceful public policy interventions are required to reduce plastic production.

2.1. Introduction

The solid waste sector is a significant source of GHGs, including methane (CH4), nitrous oxide (N_2O), and biogenic and fossil carbon dioxide (CO_2). Traditional calculations indicate that 3.3% of global GHG emissions originate from the waste sector.[16] The mitigation potential of the waste sector through zero waste systems, however, is much larger than this figure implies. Globally, 70% of total emissions come from the material economy, from extraction through disposal.[17] In the U.S., 42% of GHG emissions are associated with the lifecycle of all products.[18] Good waste management—which includes strategies that separate organic waste and prioritize reduction, reuse, and recycling (in that order)—will sharply reduce powerful, short-lived GHGs such as methane as well as reduce emissions from other sectors (such as mining, farming, manufacturing, transportation, and agriculture). As a result, the mitigation potential of the solid waste sector is greater than its total emissions, making it a potential "net negative" sector.[19]

Contrary to the claims of the so-called waste to energy industry, converting mixed solid waste to energy is an approach to net negative emissions that has not proved effective. The most common technology used for waste-to-energy, mass-burn incineration, emits far more GHG emissions than the energy it displaces.[20] Rather than reducing emissions in the power sector, it increases them. As countries decarbonize their electric grids, this discrepancy will only increase. Other technologies such as pyrolysis, gasification, and plasma arc have failed to achieve technological or commercial success.[21] Landfill gas collection, while frequently required to mitigate methane emissions, is of uncertain efficacy.[22] Of waste-to-energy technologies, only anaerobic digestion has proved successful, but it requires clean organic inputs rather than mixed waste.

Zero waste systems, on the other hand, reduce GHG emissions through multiple avenues: separate collection and treatment of organic waste avoids landfill methane emissions; waste avoidance and recycling reduce "upstream" emissions caused by natural resource extraction, manufacturing, and transport associated with the production of new goods; ending waste incineration and open burning eliminate their direct emissions of fossil and biogenic CO_2; and the application of compost or digestate to land can enhance the carbon uptake of soils.



2.2. **Tackling landfill methane through organic waste**

2.2.1. **Methane emissions**

Methane is a powerful GHG, trapping 82.5 times as much heat as CO_2 over a 20-year timespan.[23] It is responsible for approximately 0.5°C of warming in today's world.

Fortunately, methane also degrades relatively rapidly over an average period of 12 years.[24] Reducing methane emissions is therefore one of the quickest ways to reduce global heating and help us stay below 1.5°C of warming,

the target set by the Paris Agreement. Swift emissions reductions will buy countries and communities around the world the much needed time they require to decarbonize their economies and societies.

Globally, the waste sector is responsible for approximately 20% of anthropogenic methane emissions, making it the third largest and most rapidly growing source sector.[25] Landfill methane emissions result from the decomposition of organic waste—primarily food scraps—under anaerobic (oxygen-deprived) conditions.[26] In some cities, landfills are the dominant source of methane emissions.[27] Recent studies suggest that these numbers may be significantly underestimated.[28] Measuring the exact amount of methane emitted from landfills is challenging, as the methane generation rates vary greatly between landfills and even from spot to spot on the same landfill depending on temperature, moisture, and organic content.[29] Due to the inaccuracy of conventional measuring methods such as the Intergovernmental Panel on Climate Change (IPCC)'s "first-order decay model," uncertainty of the actual scale of methane emissions remains to be addressed.[30]

While waste composition and climate affect methane emissions, the waste management techniques and technologies employed are the most important factors.[31] Open dumps, which are often found in the Global South, are prone to smolder or to catching fire, reducing methane emissions but becoming major sources of toxic air and water pollution. Fully enclosed, compacted, and sealed landfills, which are typically found in the Global North, promote anaerobic decomposition of the organic waste into methane. Bioreactors, in which landfill leachate is recirculated into the landfill, increase methane generation by filling air voids and providing water to anaerobic microbes. Biologically active cover, on the other hand, contains methanotrophic microbes that consume methane before it reaches the atmosphere, making it the obvious choice for managed landfills during the transition to separate collection, composting of organics, and other zero waste solutions.

@Lars Schoebitz

Global Warming Potential (GWP) and Calculations

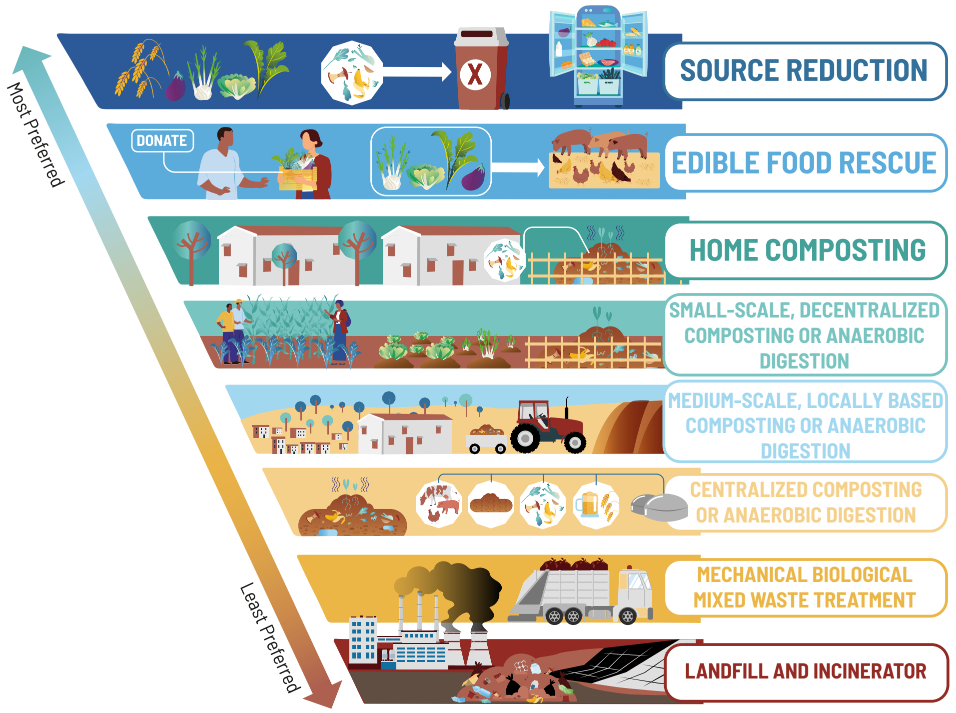
Methane is a much more powerful GHG than carbon dioxide, but has only a brief atmospheric lifetime: 12 years on average as opposed to ~400.[32] Global Warming Potential (GWP) is a tool used to aggregate the effects of GHGs with very different atmospheric lifetimes. By construction, the GWP of CO_2 is 1; for other gasses, the GWP depends on the timeframe considered. For a short-lived gas like methane, the impact is concentrated in the first decade, so the 20-year GWP (82) is much higher than the 100-year GWP. Both GWPs are scientifically correct, and the choice of which to use is a policy, not scientific matter (IPCC AR6 WG1 TS 3.3.3). Whereas the initial Paris Agreement rule book prescribed the use of 100-year GWPs for national reporting, the growing urgency to address short-term emissions is driving increased use of 20-year GWPs in policy.

The Inédit calculator used in this report relies upon an underlying scientific literature that uses 100-year GWPs. As a result, it effectively understates the impact of methane emissions. The practical impact is that reducing the organics sent to landfill is, if anything, far greater than expressed in the case studies on page 48.

2.2.2. **Alternatives to landfilling**

2.2.2.1. **Waste prevention and food rescue**

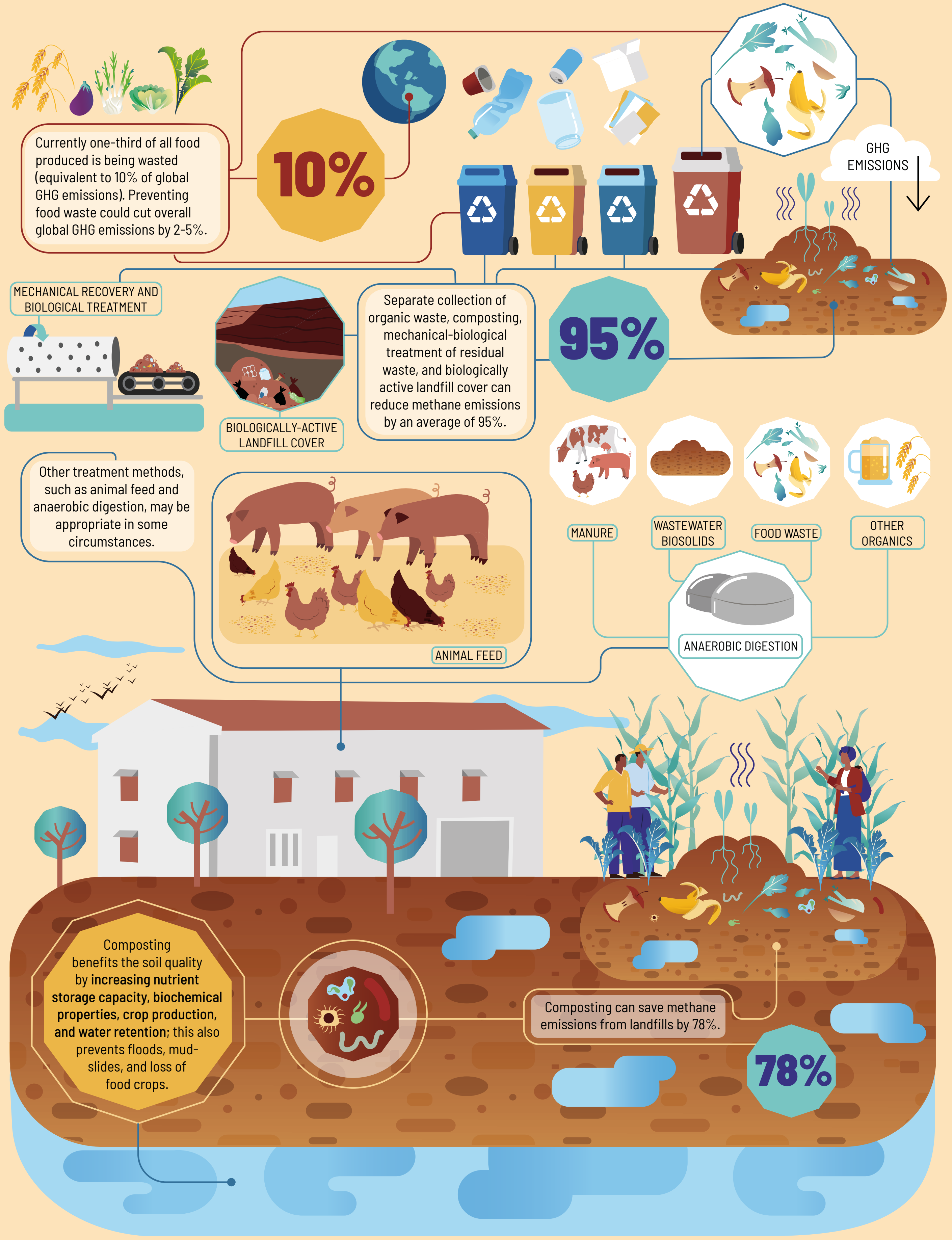
The best approach to reducing landfill methane emissions is to avoid landfilling organic waste, which represents the largest proportion of the solid waste stream. As with other waste streams, waste prevention or avoidance has the greatest impact. An astonishing one-third of all food produced is wasted, and is responsible for as much as 10% of global GHG emissions.[33] Tackling food waste reduces emissions between 0.8 and 4.4 tonnes CO_2e per tonne of waste prevented, and comprehensive food waste reduction could lower global GHG emissions by 2% to 5%.[34] Most of these emissions reductions occur in the production and transportation of food even before it reaches consumers, which points to the gross inefficiencies in our current food systems.[35] Of the eight cities studied, only Bandung, Indonesia considers an action plan to reduce food waste; this is a neglected strategy that deserves more attention.



Source: Institute for Local Self-Reliance

When prevention is not possible, recovery should be the next priority. Food rescue and redistribution programs to communities in need, through networks of food banks, food pantries, grocery stores, restaurants, and other food retailers, can yield both significant emissions reductions and increased community resilience. For example, in just three years, Milan, Italy's food rescue program has been able to divert 130 million tonnes of food waste from landfilling annually, putting the city well on track to meet its goal of 50% food waste reduction by 2030.[36]

THE UNTAPPED POTENTIAL OF ORGANIC WASTE
TO COOL THE PLANET



2.2.2.2. Separate collection and treatment

For the organic waste that cannot be prevented or rescued, the best practice is separate collection and treatment.[37] Separate collection at the point of generation (households, businesses, etc.) is critical to avoid cross-contamination of different waste streams, which lowers the utility and value of both organic and non-organic materials. In this context, the most prevalent and easiest-to-implement treatment method for organic waste is composting.

Composting, the microbially-aided aerobic (i.e. oxygenated) decomposition of organic waste, can be carried out at a range of scales, from household to city-wide. Well-run composting operations do not attract vermin or create odors. Composting prevents an average of 78% of methane emissions that would otherwise be emitted from landfills, leading to significant waste sector emissions reductions.[38] Moreover, the scalability of composting initiatives (from backyard to industrial) allows for a range of waste management approaches, including highly decentralized systems. One advantage of decentralization is that it can significantly reduce transportation costs and the climate and public health impacts of heavy truck traffic. Care must be taken to ensure sufficient aeration of the compost, which prevents anaerobic digestion and waste water and methane formation. As the organic waste breaks down, it emits water vapor, biogenic CO_2, and small quantities of nitrous oxide (N_2O). However, a significant portion of the carbon remains in the final product— a nutrient—and organic matter-rich soil amendment.[39] This compost can be used for agricultural purposes, stormwater management, and landscaping, among other uses.

Other treatment methods for source-separated organics include anaerobic digestion and animal feed.[44] Anaerobic digestion produces methane-rich biogas from organic waste in an enclosed vessel, avoiding the problem of landfill methane leakage. The biogas is usually burned on site either for heat or electricity generation. This produces biogenic CO_2 emissions (see page 25) but can replace fossil-based fuels, particularly for cooking. Digestate, a slurry of partially decomposed organic matter, is the principal byproduct. It is typically dewatered, composted, and used as a soil amendment. Anaerobic digestion works best at small scales; its small footprint makes it a good choice for congested urban environments with high volumes of organic waste and little space for composting facilities.[45]

Composting success story from Pune, India

A composting project organized and managed by the cooperative of waste pickers SWaCH in Pune (India) serves the dual benefits of reducing methane emissions and producing compost by diverting organic waste from being dumped at a landfill (where methane is generated when organic waste decomposes) to an at source composting facility (aerobic composting). Moreover, SWaCH is India's largest cooperative wholly owned by self-employed informal waste-pickers. It creates sustainable livelihoods for the waste-pickers, particularly for disadvantaged women, producing valuable compost that combats highly problematic soil degradation.

Such a project is highly suitable in the Global South because the waste produced is mostly organic: 53% and 56% in middle- and low-income countries respectively.[40] In Pune, the proportion of household organic waste (the largest source of waste) is 72%. SWaCH provides the expertise and materials needed to install the new composting infrastructure in both residential and commercial spaces, and it assigns a trained waste picker to maintain the composting unit. The waste is collected by trained waste pickers from citizens' doorsteps and delivered to the composting site. Currently, 71 waste-pickers are managing 7,000 Kg organic waste daily at 121 decentralized locations. SWaCH also helps individual community members maintain their existing composting sites, which makes them eligible to apply for a 5% tax cut on their property taxes.[42]

This is a clear example of how a single project can mitigate GHG emissions, increase the capacity to adapt to climate change by improving the health of land, and provide additional benefits through the creation of jobs and reducing gender inequality. SWaCH's work has been internationally recognized and it has received several awards.[43]

While the prospect of generating energy from organic waste is enticing, anaerobic digestion should be employed with caution. It is much more costly to implement than composting and requires technical training to operate effectively.[46]

If the process is mismanaged, there can be significant negative repercussions. Mismanagement includes landfilling the digestate, flaring the biogas instead of burning it for energy generation, burning fossil fuels to increase the processing temperature, and processing purpose-grown crops instead of food waste.

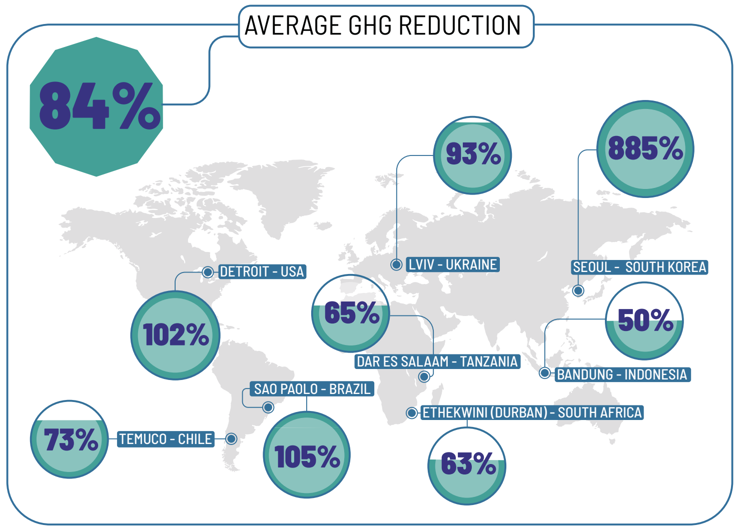
Using organic waste as animal feed is another way of diverting organic waste from landfills. Food scraps have been fed to animals for millenia, and it remains a common strategy in rural areas worldwide. Animal feed is a good way to capture the nutrient value in food waste; it is also a good substitute for resource-intensive feed crops. The methane reduction potential of animal feed has yet to be robustly quantified, but one lifecycle analysis found that this treatment method outcompetes compost and anaerobic digestion in terms of its overall GHG emissions reduction performance.[47] However, precautions must be taken to avoid potential disease transmission, and industrial agriculture is, of course, a major source of GHG emissions.

In all the cities we analyzed, except Seoul, separate collection and treatment of organics has the greatest potential to reduce GHG emissions.

Separately collecting and treating the waste—usually through composting—reduced GHG emissions by 62%.

This impact is, if anything, understated, because it uses the 100-year GWP value for methane (see box). Seoul is an exception because it already diverts 96% of its organic waste through source-separate collection, so its emissions are primarily from incineration rather than landfilling.

Map showing the potential to cut emissions across cities



The bottom line is that good source separation is the key to success with any organic waste management program. Source separation and separate treatment of organics can obviate the need for downstream mitigation measures such as landfill gas collection.[48] Source-separated waste can be successfully diverted from disposal through recycling or composting. Cross-contamination, on the other hand, reduces the quantity and quality of the recyclable and compostable materials, and can cause operational failures in some treatment technologies, such as anaerobic digestion.[49] Source separation is particularly important to ensure high-quality compost for land application. In California, high-quality compost fetches a premium market price, which significantly offsets the costs of waste management. The state's preliminary budget also includes USD 180 million to implement state requirements to separate and compost organic waste.[50]

Good source separation practices rely on the cooperation of individuals and businesses, which in turn depend on continual outreach and culturally competent engagement from the local waste management authority, along with a clear, easy-to-use source separation scheme.

Successes in locales as different as Italy, India, South Korea, and the U.S. attest to the viability of source separation schemes, regardless of culture, climate, or political circumstances.

2.2.3. **Residual waste**

Even with the best food waste prevention, source separation, and treatment practices in place, some organic waste will continue to be mixed into residual waste for the foreseeable future. To address emissions from this "dirty organic fraction," the European Union has implemented policies to dramatically reduce the landfilling of untreated waste.[51] As one of the aims of zero waste systems is to continually reduce the quantity of waste sent to disposal, it is important to not over-build infrastructure for residual waste management; otherwise, the sunk costs of this infrastructure create a financial incentive to continue generating large quantities of waste, thus disincentivizing waste reduction and diversion practices.

As long as some organics remain in the residual waste, such mixed material should undergo "biological stabilization," which refers to a range of treatments from mixing and aeration techniques to more complex material recovery and biological treatment systems. The aim of biostabilization is to reduce the potential of the residual waste to generate methane. Although the process is similar to composting, it does not generate usable compost because the residual waste is mixed and contaminated. One common approach to stabilizing residual waste prior to landfilling is mechanical recovery and biological treatment, which has been shown to reduce landfill methane generation by 80-90% or more.[52]

A final mitigation step for landfills that continue to receive a dirty organic fraction or for older landfills with organic waste in place is the use of biologically active landfill cover (biocover). Although one study found that only 9% of landfill methane emissions originate in decommissioned landfills, these sites can continue to emit methane decades after being rendered out of operation.[53] Biocover refers to soil and compost that contain methanotrophic microbes, which feed on fugitive methane emissions from the landfill. Studies have shown biocover to reduce fugitive methane emissions by an average of 63%.[54] In some cases, biocover is so effective it not only consumes all the fugitive methane emissions but draws down ambient atmospheric methane.[55]

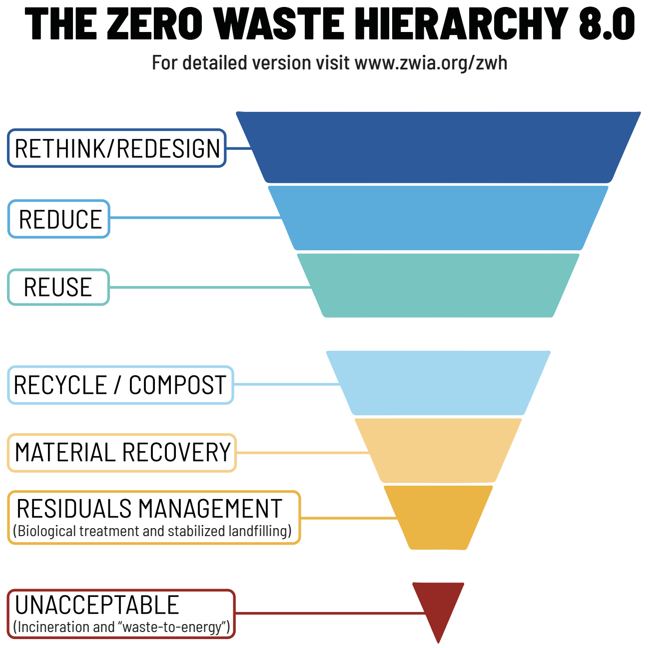
Biocover compares favorably to landfill gas capture systems, which aim to capture and burn the methane-containing landfill gas. Landfill gas capture has highly variable mitigation efficacy and is subject to uncertainties about fugitive emission rates.[56] Long-term problems include breakage of the pipes that collect landfill gas, an inability to recover energy from landfill gas that is low in methane content, and air pollution from the gas combustion. Landfill gas collection systems are one of the costliest approaches to methane mitigation, which creates a perverse incentive to maintain high rates of methane generation by landfilling organic waste that could have been returned to the soil.

Organic waste prevention, source separation, and separate treatment are essential elements to mitigate methane emissions; they are also all essential to the broader goal of building zero waste systems. As organic waste is one the largest fractions of municipal solid waste, successful organic waste diversion programs dramatically reduce the quantity of residual waste requiring additional treatment and disposal.

2.3. **Scaling up reduction, reuse, and recycling of non-organic waste**

2.3.1. **Waste hierarchy**

While tackling organics is critical to deep emissions cuts in the waste sector, other materials—particularly paper, cardboard, metal, glass, textiles and plastic—hold the key to net negative emissions. Here, the waste hierarchy is the best guide to minimizing GHG emissions, with source reduction being the most impactful and preferred option. Source reduction, reuse, and recycling all reduce emissions by decreasing the demand for raw materials, the energy required to manufacture goods, and the need for associated transport. In national inventories, these emissions are tallied in the industrial, agricultural, transportation, and energy sectors—not the waste sector—which explains how zero waste can reduce more emissions than the waste sector produces



A study conducted by the U.S. EPA demonstrated that waste prevention showed net negative impacts and the biggest climate benefits among existing waste management methods, such as recycling, composting, incineration, and landfilling.[57] Strategies for source reduction include restricting the production and distribution of single-use items and packaging and designing products to be durable, repairable, reusable, and fully recyclable or compostable. In the circular economy, products should be sourced from reused, recycled, or renewable non-toxic materials to minimize the need for extraction and the use of virgin natural resources, and cities should institutionalize alternative delivery systems to enable and strengthen reuse and refill models.

The emissions reductions from source separation and recycling can also be quite substantial. Our analysis shows that **Detroit, Lviv, and São Paulo could each reduce their GHG emissions by more than 20%** through effective source-separated collection of readily recyclable materials—metals, glass, paper, and cardboard, as well as small quantities of plastic and textiles. Other cities, which already have efficient formal (Seoul) or informal (Durban) recycling sectors, have less scope to improve; in these cases, it is important to avoid problematic approaches such as waste incineration that would negatively affect existing recycling systems.

The mitigation potential of recycling depends on the energy and emissions intensity of the material, which ranges widely; for energy-intensive materials, such as metals, the reductions can be as high as 96% of the emissions associated with producing the original product.[58] The potential for mitigation through waste avoidance and recycling often goes unrealized due to misaligned economic incentives. For example, recycled plastic resin struggles to compete with subsidized virgin resin, depressing recycling rates well below technically feasible levels.[59]

2.3.2. **Plastic**

Plastic is a ubiquitous and uniquely problematic material. Plastic production is growing at 3.5-4% per year, doubling every 20 years.[60]

> *As 70% of plastic becomes waste within a year of its production, plastic waste generation is also growing at a similar rate.*[61]

As a fossil fuel product, plastic has an enormous carbon footprint, two-thirds of which is in the production phase. Additional CO_2 is emitted when carbon is burned, e.g., in incinerators. Judging by current investments in expanded plastic production capacity, from 2015 to 2050, the world's plastic GHG footprint will be 129 billion tonnes combined.[62] In the U.S. alone, the GHG emissions from plastic production and destruction is projected to exceed the power sector's GHG footprint.[63] If plastic were a country, its global carbon footprint would be the fifth largest among all nations.[64]

Unfortunately, recycling is not as effective for plastic as for other materials: plastic waste is a mix of different polymers, additives, contaminants, and other materials that are difficult or impossible to effectively separate. As a result, very little plastic (9%) is successfully recycled.[65] Alternative processes such as pyrolysis and solvolysis, which the plastic industry calls "chemical recycling," have high energy demands, low efficiencies, and enormous carbon footprints.[66] However, even perfected recycling technologies would not address the upstream emissions of growing plastic production, which is incompatible with a net-zero emissions goal. Source reduction is therefore the key to constraining plastic's GHG footprint.

Plastic production needs to shrink rather than grow in the coming years.[67] But reduced production is not in the interests of the oil, gas, and petrochemical industries, which are currently investing billions of dollars in expanding capacity. Plastic use is driven not by increasing demand but by increasing supply, with the industry actively seeking out new markets for plastic to compensate for stagnant sales of transportation fuels.[68] Demand-side measures, such as promoting plastic-free and reuse-based business models, while important, are thus insufficient to check growth in plastic production. Forceful public policy interventions are required. The most popular policies enacted to date are bans on categories of plastic, such as single-use plastic and hard-to-recycle packaging. Additional policies will probably be required, such as banning new plastic production facilities and expanding the categories of banned plastic. Other potential policy measures, such as a plastic tax, have yet to gain consensus. The universally recognized need for stronger policies is captured in resolution *UNEP/EA.5/Res.14* of the United Nations Environment Assembly, which initiated a negotiation process toward a new global treaty on plastic. For the first time, a global cap on plastic production is on the table.

The plastic that is produced should be designed for reuse and recyclability. This means avoiding the use of additives, toxicants, mixed polymers, unrecyclable polymers (such as polyvinyl chloride) and multi-material packaging that deter mechanical recycling. At the same time, there is little sense in investing heavily in heavy industrial facilities (such as chemical recycling and incineration) to handle waste streams that are slated for phase-out; these sunk costs will create incentives to continue production of problematic plastic.

Cities have taken the lead in banning unnecessary and non-recyclable plastic, and these bans have often been stepping stones to state/provincial-level and even national bans. Municipal-level bans of single-use plastic have been proposed for seven of the cities in this study. Despite the relatively small tonnage of waste these bans target, the GHG emissions reductions can be sizable, particularly in cities that use large quantities of plastic. In addition to reducing GHG emissions, these bans are important for flood control, reduction of waste management costs, and preventing plastic pollution in the environment.

@Ivan Radic

2.4. **Ending waste combustion**

Incineration and open burning of waste (the latter usually in concert with open dumping) are common practices in the Global North and Global South, respectively. Both emit large quantities of GHG, primarily fossil CO_2 (from the combustion of plastic), biogenic CO_2 (from the combustion of paper, cardboard, and food waste), and N_2O, as well as particulates. Although there is relatively little data about the impact of open burning, it is universally acknowledged to be a problematic practice that must be phased out for both climate and environmental health reasons. Open burning and open dumping primarily occur where local authorities lack the resources to collect and properly manage waste. These practices are aggravated by the dramatic rise in plastic production, which is both increasing the quantity of waste and changing its composition, leading to higher GHG and toxic emissions when burned.

> *Incineration is the most expensive waste management strategy and a major source of GHG and toxic emissions.*[69]

Even with emission savings from electricity generation taken into account, each tonne of plastic burned at that incinerator would result in the release of around 1.43 tonnes of CO_2.[70] Its high capital costs and required technical expertise create a risk of locking cities into undesirable practices for decades.[71] Incinerators have performed best in cities where the waste heat can be used in a district heating network; otherwise, the electricity produced is more carbon intensive than the electric grid, implying that it will displace lower-emitting forms of electricity.[72] In developing countries, incineration is not practical due to high moisture content and low calorific value (heating value) of the municipal waste stream.[73]

Nevertheless, many studies continue to tout incineration as a mitigation measure because it avoids landfill gas emissions and produces energy. These studies rely on worst-case comparisons in order to conclude that incineration is superior. In particular, they usually assume that unseparated municipal waste, with high organic content, will be sent to landfill without significant methane remediation measures.

While that situation describes current practice in many locations around the world, it is by no means universal. Most importantly, it is unlikely to continue. The establishment of net zero emissions goals under the Paris Agreement means that landfills, as significant methane emitters, can no longer be regarded as an acceptable part of the status quo "business as usual." In the European Union, for example, pretreatment for landfilled waste is now obligatory, and countries must put in place plans to avoid landfilling organic waste. The Paris Agreement has established a clear benchmark—zero emissions—[74] against which to measure climate projects. A project can no longer claim to mitigate emissions on the basis that its emissions, although high, are lower than a hypothetical and completely preventable alternative; all projects must aim for zero emissions. For incinerators, this implies shutting down, which both removes a major source of emissions and contributes to a cleaner electric grid.[75]

This is precisely the situation in Seoul, the only city in the study that relies significantly on incineration. In Seoul, emissions from incineration are five times higher than from landfills and nearly twice as high as replacement energy sources. Eliminating incineration would transform Seoul's waste sector, increasing its emissions reductions by an order of magnitude. Similarly, ending open burning of waste in cities where it is prevalent is important, although much harder to quantify due to lack of data on the practice.

2.5. **Advantages of soil carbon storage**

Composting has many benefits (see section 3.4.), including direct and indirect mitigation effects. The mitigation effects of applying compost, including the digestate resulting from anaerobic digestion of organic waste, to soil are manifold: GHG emissions associated with the use of synthetic fertilizer, peat, and/or pesticides are avoided; N_2O emissions related to use of synthetic fertilizer are reduced; emissions associated with tilth and irrigation are decreased; and the uptake of atmospheric carbon by the soil and plants is enhanced.[76]

Compost is a carbon-rich soil amendment. When applied to soil, it stimulates myriad biological processes that result in a portion of the carbon being emitted as CO_2, and another portion stored in the soil and below-ground biomass. How much carbon can be stored in soil, and for how long, are open scientific questions. In Marin County, California, a single application of compost on degraded rangeland resulted in dramatic increases in water holding capacity, forage productivity, and carbon sequestration.[77] Soil carbon storage is strongly affected by temperature, precipitation, land use, soil type, and degree of soil degradation, and thus its potential is highly variable and site-specific. While soil carbon storage is no substitute for emissions reductions, degraded agricultural land is a global problem, and returning it to health would imply a drawdown of 15.12-23.21 GT of carbon,[78] 11-17% of the amount of soil carbon that has been lost since humans first settled into agricultural life around 12,000 years ago.[79] At a minimum, compost provides an excellent alternative to synthetic fertilizer, which is an energy and emissions-intensive fossil fuel product.

@Rommel Cabrera/GAIA

@Nipe Fagio

The informal sector and GHG mitigation

The informal sector plays a critical role in waste management, particularly but not exclusively in developing countries. In most developing countries, the informal sector is responsible for the great majority of recycling, collecting up to 45% of the total waste stream.[80] This collection happens at the doorstep, at intermediate transfer points, and at open dumps. This activity, also known as waste picking, reduces collection costs to the public, provides raw materials to formal businesses, and reduces GHG emissions.[81]

The recycling market is largely unregulated and highly volatile, resulting in the collection of only high-value recyclables (metals, glass, paper products, and a few types of plastic). Plastic recycling markets are further undermined by additives and contaminants in the plastic and the low cost of virgin polymer, making most plastic collection uneconomical. Source-separated organics could provide an additional income stream for waste pickers, but the market value of the final product (compost) is usually not enough to justify the labor and transportation costs. In addition, there are practical challenges in getting householders to practice source separation and in finding land and equipment for composting. Many projects have successfully overcome these hurdles through collaborations between NGOs and local governments. Householders, local governments, or both bear the cost of the program, which is defrayed by sales of compost. The benefits of the program, in terms of reduced GHG emissions alone, outweigh its costs.

Constituting between 0.5% and 2% of the global population (12.5-56 million people), the informal waste sector is an important stakeholder in existing waste management systems and must be incorporated into planning for system improvements.[82] Experts in the field of informal recycling have recommended a participatory governance framework including legal recognition of the access to waste, proper contracts, support for member-based organizations, provision of infrastructure, and social protection schemes.[83] Informal sector integration can yield beneficial social and economic outcomes while unlocking the potential for greater GHG mitigation, e.g., through cost-effective collection and treatment of source-separated organics.[84]

Biogenic CO_2

Biogenic CO_2 is defined as CO_2 emitted to the atmosphere from the combustion or decomposition of recently-living biomass, including wood, paper, food, and other plant materials. It is distinct from fossil CO_2, which results from the combustion of carbon that has been locked in the earth's crust over geologic time. Accounting for biogenic CO_2 is more complicated than accounting for fossil CO_2 because it is also emitted by plants, animals, and microbes as part of the natural carbon cycle. Absent human influence, this natural carbon cycle is assumed to be roughly in balance, at least over policy-relevant time scales (e.g., less than 100 years). The challenge is in determining how much biogenic CO_2 human activity adds to the atmosphere additional to the natural baseline. Unfortunately, the natural baseline is difficult to calculate; there is considerable scientific uncertainty about the pools and dynamics of soil carbon, for example. There are also significant challenges in measuring biogenic CO_2 fluxes from land, crops, and forest. (Fossil carbon, on the other hand, has virtually no natural transfer to the atmosphere, so all fossil CO_2 emissions are anthropogenic in nature).

In its guidelines for national emissions inventories, the IPCC instructs national authorities to report biogenic emissions separately from fossil CO_2 emissions. This is, in part, to prevent the greater uncertainties around biogenic CO_2 from obscuring the picture of fossil emissions. The IPCC also indicates that biogenic CO_2 should not be included in the total emissions of the power sector (which includes waste-to-energy incinerators and biomass-fired power plants) because these emissions are already accounted for in the Agriculture, Forestry, and Land Use (AFOLU) sector; reporting them twice would amount to double-counting. This guidance has been widely misinterpreted as indicating that biogenic emissions do not add to climate change or do not need to be reported at all. This misinterpretation has been thoroughly discredited[85] yet remains common practice, allowing waste-to-energy (WTE) incinerators and cement kilns to take advantage. The scientific best practice is to report biogenic and fossil CO_2 emissions separately, as the U.S. EPA does.

Biogenic CO_2 emissions in the waste sector derive largely from the combustion or aerobic decomposition of biomass (food waste, yard/garden waste, wood, and paper products). In addition, the CO_2 that results from the combustion or decomposition of methane (from landfills or anaerobic digesters) is biogenic. If the methane itself is released, that is not considered biogenic, since methane generation is the result of human activity.

Waste management techniques differ significantly in their biogenic CO_2 emissions. Incinerators and open burning convert virtually all carbon in the waste to CO_2, immediately emitting it to the atmosphere. Landfills convert much of the organic carbon to methane or CO_2, but more slowly; best estimates indicate that approximately 50% of the organic carbon buried in landfills will remain there for at least one year.[86] Wood, in particular, is resistant to decomposition in landfills and may persist for centuries. Composting also loses a large proportion of its organic carbon as CO_2 during the composting process, but can be an effective way to increase carbon storage in soil, particularly degraded soils.[87] In many cases, this has resulted in significant long-term soil carbon storage.

Accounting for the different fates of biogenic carbon is complex. The most accurate approach is to account for all fluxes. The calculator used in this study omits biogenic emissions because it relies on the underlying published literature, which is inconsistent in its approach to biogenic CO_2. As a result, our calculations understate the benefits of composting and ending incineration and open burning.


@Francesca Mold/UNMISS

3. Zero waste and climate adaptation

Chapter summary

- Cities can withstand the impacts of climate change and build climate resilience by implementing zero waste strategies.
- Cities can lower flood risks through plastic bans and universal collection systems that keep waste from blocking drains and stream flows. Countries including Bangladesh, India, Botswana, Rwanda, South Africa, Tanzania, and Uganda have already adopted plastic waste reduction measures to prevent flooding.
- Proper organic waste management and prevention of drain blockages can prevent disease transmission via rodents, flies, and other disease vectors. The interlinkages between improper solid waste management, drain blockages from waste—especially plastic— and increased breeding sites were observed in Ghana and India, among other countries.
- Composting creates multiple benefits to climate adaptation; it increases nutrient level in soils, improves soil structure, mitigates surface and groundwater contamination, and prevents soil erosion and associated natural disasters such as flooding and mudslides.

3.1. Introduction

Climate change is expected to increase the frequency and severity of extreme weather events and health hazards. Poor waste collection and management are among the factors that leave cities exposed to the threat of climate impacts and their related public health risks. These include waste-blocked drains and water channels that contribute to flooding; improperly managed collection sites that harbor rodents, flies, and other disease vectors; and toxic emissions and leachates from waste facilities that kill plants and animals essential to aquatic or terrestrial systems, resulting in compromised soil health and harm to biodiversity.

Yet conversations about climate change adaptation—measures to reduce the vulnerability of natural and human systems against the impacts of climate change—rarely recognize the role of waste management, usually limiting such discussion to the relocation of waste facilities and to the reinforcement of infrastructure in response to high temperatures, floods, droughts, storms, and rising sea levels.

While these strategies focus on disaster risk reduction and safe continuation of key services related to waste management, zero waste solutions hold great potential to protect communities from climate-induced environmental health risks. Research and best practices already exist, providing evidence that implementing zero waste strategies can help cities withstand the impacts of climate change.

This chapter discusses three zero waste strategies that can help cities adapt to and further prevent climate change:

1. plastic bans and universal collection systems to lower flood risks;
2. proper organic waste management and prevention of drain blockages to prevent disease transmission;
3. composting to increase soil resilience.

3.2. Zero waste and flood prevention

3.2.1. Impacts of flooding

As the global temperature rises, the occurrence and intensity of extreme flood events are expected to increase.[88] A warmer atmosphere holds more moisture and heat, resulting in frequent intense downpours, heavy rains, and rain storms that increase the chance of floods.[89] Floods can have disruptive and distressing consequences to communities; they threaten lives, inundate properties, and damage essential infrastructure. Massive floods destroy livelihoods, hinder economic growth, and can even lead to politically volatile situations, as seen in Africa, Asia, and the Middle East in the past decade.[90]

Common impacts on human health include injuries, infections, and mental health problems. A study of flood hazards documented testimonials from local residents in poor districts of Manila, Philippines, who experienced respiratory infections, skin allergies, and gastro-intestinal illnesses, with children at higher risk.[91] Some of the respondents of the survey even stated that they witnessed sudden deaths or serious illness after certain floods, as the community lacked proper medical care.[92] Although post-flood outbreaks of infectious disease are relatively rare, cholera cases have been reported in Zambia in 2010, where the Ministry of Health confirmed 564 cases after a flood, with 30 deaths in Lusaka.[93] Poor wastewater management and inadequate access to safe drinking water exacerbates these health threats.[94] Longer-term health effects of floods can be caused by displacement, continued shortages of safe water, lack of access to public services, and delayed recovery of health conditions.[95]

While poor waste management can be a major contributing factor to floods (as discussed in the following section), flooding itself poses a threat to solid waste infrastructure like landfills. Without proper water catchment systems in place, heavy rain and subsequent flooding from extreme storms can undermine landfill foundations, releasing leachate into groundwater and causing waste to clog other infrastructure.[96] In Austria, about 30% of landfills were located in flood-prone areas, only 5% of which were equipped with proper protection facilities.[97] The burden borne by impacted communities is expected to intensify as climate change escalates, especially among people in low-income communities located in flood-prone sites.[98]

@Kira Erwin

3.2.2. Waste worsens flooding

Unmanaged or improperly managed waste exacerbates flooding, especially in informal settlement areas with insufficient drainage systems. Even in planned urban environments, waste clogging up drainage systems increases vulnerability to flooding. The Covid-19 pandemic further exacerbated this problem, with discarded personal protective equipment increasing the volume of litter that makes its way into storm drains.[99]

The World Bank's guide to urban flood risk management, published in 2013, recognizes poor waste collection as a factor that may cause or worsen the following adverse impacts:[100]

- blocked drains that lead to flooding
- increased diseases (e.g, waste provides material on which flies lay their eggs or serves as food for rats)
- infections, especially from clinical waste and sewage
- chemical toxicity, especially from discarded medicines along with commercial and industrial waste
- contamination of surface and groundwater
- contamination of the food chain

Dumping of uncollected waste is the most prevalent cause of flooding in places with inadequate waste collection systems. In Saint Louis, Senegal, the lack of household waste collection systems coupled with wastewater discharged from households and other establishments was the main cause of blockage in natural drains; inadequate drainage systems aggravated the situation.[101] In Manila, Philippines, dumping of solid waste was identified as a key factor in the prevalence of infections during and after flood events, along with blockages to drainage channels and poor sanitation systems.[102] In Lagos, Nigeria, uncollected municipal solid waste dumped in unauthorized places is also one of the major causes of flooding. Between 2007 and 2013, waste that clogged drainage channels and impeded the free flow of storm water during heavy rainfall resulted in floods on 126 streets.[103]

Drainage issues have provoked swift waste reduction measures, as seen in Rwanda, Tanzania, and Uganda— countries that all banned plastic bags to prevent flooding. Similarly, South Africa and Botswana have imposed taxes on the distribution of plastic bags in recent years.[104] After experiencing a tragic flood in Accra in 2015, in which at least 150 people died, Ghana is also considering implementing restrictions on the production and use of plastic bags.[105]

3.2.3. Implementing zero waste systems as flood prevention measures

The blockage of drains resulting from poor management of waste can effectively be prevented by minimizing waste generation and subsequent waste leakages.

In Bangladesh and India, there is a clear link between plastic waste and flooding. In 2002,

> *Bangladesh became the first country in the world to ban all polythene bags, after finding that such waste was responsible for a 1988 flood that submerged half the country, and for the ongoing spread of water-borne diseases.*[106]

India also banned most plastic bags in 2005 following a flood, caused by mismanaged waste and drainage systems, that incurred deaths of more than 1,000 people, mostly in Mumbai.[107] In these cases, the devastating impacts of floods prompted legislation banning the use of plastic bags, which shows how cities can take action to help prevent future flood events by applying precautionary principles to minimize environmental, social, and economic risks associated with plastic bags blocking waterways.[108]

An academic study estimates that improving existing drainage canals and proper solid waste management would help prevent about 322 hectares of land from flooding in Sylhet, Bangladesh.[109] It proposes: (i) source separation of organic waste; (ii) proper management of plastic waste; and (iii) local composting of organic waste or proper disposal in landfills as possible solutions, with a note that "such interventions can be implemented within reasonable and short time periods."[110]

3.3. Zero waste and insect-vector control

3.3.1. Climate change and increase in vector-borne diseases

As climate change accelerates, raising global temperatures and causing heavier rainfalls and subsequent flooding, the changing climate can provide conditions that are favorable to breeding of blood-feeding arthropods, such as mosquitoes, ticks, triatomine bugs, sandflies, and blackflies,[111] which transmit vector-borne diseases such as dengue fever, malaria, and lyme disease. The risk of transmission increases because the cold-blooded arthropod vectors are especially sensitive to climatic factors; in warmer climates, they grow and reproduce faster, partly due to faster digestion of blood.[112] More rainfall can also provide more breeding sites and higher food availability.[113] Warmer climate and shorter winter periods also contribute to an increase in rodent population,[114] and heavy rainfall can spread rodent-borne bacterial diseases.[115]

@Wolfgang Hasselmann

3.3.2. **Correlation between waste and vector-borne diseases**

In addition to the existing factors in vector-borne diseases, such as seasonal weather variation, socioeconomic status, insufficient vector control programs, environmental changes, and drug resistance, improper waste management can further add to the challenge of disease control.

As seen in the previous section on flooding, waterways clogged with inadequately managed waste cause floods, which offer favorable breeding grounds for many disease vectors. Plastic bags are often the major obstacle to proper waste management and drainage improvement, prompting bag bans in a number of countries and cities, notably in the African region. In Southern Ghana, improper solid waste management and drainage channels blocked by waste—especially plastic litter—increased the presence of permanent mosquito breeding sites.[116] Another study conducted in coastal cities in Ghana drew similar conclusions on the correlation between waste management and the breeding of mosquitoes, further emphasizing the potential impact of future climate conditions.[117]

Discarded containers, cans, and car tires may also provide breeding spaces for disease vectors by holding rainwater in them, where mosquitoes—which transmit filariasis, yellow fever, dengue fever, and several other arboviral infections—can breed.[118] A study on Aedes mosquitoes warned against continued, indiscriminate usage of plastic and poor waste management, as they increase the possibility of dengue fever transmission.[119]

Improperly managed organic waste is another major factor in breeding of disease vectors in the waste sector. Organic waste from households and businesses attracts flies and cockroaches and other potential hosts of infections.[120] In particular, a study found that sweet waste, such as unfinished chocolate cake, increased transmission of dengue vectors, with a similar effect to feeding dengue mosquitoes on sucrose, an important source of nutrition.[121]

When organic waste pollutes surface waters already contaminated with other forms of waste, mosquitoes and domestic flies can reproduce more easily.[122] In Kolkata, India, sewage channels were likely to serve as mosquito breeding sites when beverage container waste was also present.[123]

3.3.3. **Zero waste as a solution**

The combination of climate change and increased waste from growing urban populations has created novel conditions that allow disease vectors to thrive. Poor waste management further creates ideal conditions for germ-carrying pests that can spread serious, and even fatal, diseases. Implementing proper waste management is crucial to the prevention of disease epidemics and public health risks related to pests, especially in urban environments. Setting up timely and efficient waste collection systems is a critical element of pest control as it prevents waste from becoming litter, unmanaged, or overflowing. Reducing waste generation in the first place is even more effective; this can be accomplished through bans on single-use containers that serve as breeding spaces for disease vectors, and by minimizing the amount of discarded food entering the waste system through waste prevention and home composting.

@Rick Scovetta

3.4. **Soil improvement effect of composting**

3.4.1. **Climate change and soil health**

Climate change has a major impact on the physical, chemical, and biological functions of soil, a vital element of our ecosystems and agriculture. As land ecosystems are the second largest natural carbon sink after oceans,[124] healthier soils are key to tackling and adapting to the changing climate. There are several different ways in which climate change impacts the functions of soil:

- Higher air and soil temperatures increase aridity, a permanent state of water deficiency.[125] Significant **decreases in soil moisture** have been documented in a number of literature, including the IPCC AR5 which reported reduction in soil moisture in the Mediterranean, southwest USA, and southern African regions.[126] A report by the European Environmental Agency projects similar effects for the coming decades, with the rise in average temperatures and continued changes in rainfall patterns.[127] Losing the capacity to capture and store water can exacerbate desertification. Research shows that as much as 40% of the existing Amazon forest is already at the tipping point of shifting to a savannah-like mix of woodland and grassland.[128] Meanwhile, as of 2018 a total of 13 European Union Member States have declared that they are affected by **desertification**, both a consequence and a cause of climate change.[129]
- Climate impacts on soil also include **erosion**, a process by which soil is carried away by wind and, primarily, water. It can be accelerated by extreme climate events, such as intense rain, drought, heat waves, and storms. Soil erosion is expected to be on the rise around the world for the next 50 years due to climate change and intensive land cultivation.[130] Soil erosion may worsen flooding, as increased pollution and sedimentation in streams and rivers can clog waterways.[131]
- Continuing declines in soil moisture, desertification, and erosion can all **hinder agriculture** with potentially dramatic impacts on food production. A recent report by the IPCC warns that land degradation and climate change could result in a 25% food production deficit by 2050.[132] The European Parliament also recognized that irrigated crop yields will decrease by up to 20% across all of Europe by mid-2030, compared to current yields, due to warming temperature.[133]


@Swach Pune Cooperative

3.4.2. **Composting as a climate adaptation measure**

Composting of organic matter helps communities adapt to climate consequences by reducing pollution and strengthening the resilience of the soil. Such benefits of composting include the recovery of discarded materials, reduction in landfill waste and pollution from incinerators, reduced surface and groundwater contamination, reduction in soil erosion, and improvement of soil structure.[134]

3.4.2.1. **Composting as a solution to nutrient deficiency in soil**

Compost application increases the level of soil organic matter, which significantly improves the soil's capacity to store nutrients through pore spaces created by soil organisms, absorbing essential nutrients, such as nitrogen, phosphorus, potassium, calcium, and magnesium; feeding billions of crucial microorganisms; and improving water absorption.[135] Research demonstrates that compost has a higher absorption and storage capacity than other common agricultural soil amendments.[136] High organic matter content also increases soil resistance to changes in soil acidity and allows faster mineral decomposition.[137] The extensive beneficial effects of composting on soil health have been abundantly documented across the globe, and the below list categorizes some of the studies into four groups:

Improved biochemical properties

- A study conducted in Spain showed the soil quality improvement effects of compost, which increased the organic matter content of degraded soils and improved soil biological and biochemical properties.[138]
- An experiment conducted over a four-year period in Southern Italy presented the benefits of compost in maintaining an adequate level of soil organic carbon and sustaining biological activities. The addition of compost resulted in stable vegetable crop productivity and showed the best outcome for the restoration of soil carbon mineralization among various fertilization strategies.[139]
- A study conducted in West Africa pointed out that the effects of compost were clearer with a long-term experiment, in which compost amendment improved soil morphological and chemical properties.[140] As a result, composting was recommended as a sound solution for combating soil degradation and alleviating food shortage and poverty in the Sahel.
- Particularly on the effects of municipal solid waste compost, results of a study conducted in central Spain have shown that the use of compost had positive effects on the soil quality with microbial biomass carbon and enzyme activities, which improved soil perturbation or restoration over a relatively short time.[141]

Increase in crop production

- A field study conducted in Puerto Rico—under tropical conditions—demonstrated that the addition of compost increased both the quantity and the quality of soil organic matter, improving soil quality and crop production.[142]
- A study conducted in Pakistan found that the use of rice and wheat straw compost improved soil fertility and productivity.[143] Reduction in the cost of crop production was also noticed, which implied higher yield and income for the farmers practicing composting.[144] As a result, composting rice and wheat straw was recommended as an alternative to chemical fertilizers in Pakistan and countries with similar climatic and soil conditions.

High levels of nutrients

- A study conducted in Truro, Nova Scotia, demonstrated that compost-amended soils produced similar or higher yields of certain crops than fertilizer-amended soils and contained higher levels of carbon, nitrogen, phosphorus, calcium, magnesium, manganese, zinc, and boron compared with the fertilized plots.[145]
- In the UK, it was observed that compost consisting of green materials that are high in nitrogen, such as fresh grass clippings, enhanced low-grade soils. [146]
- Similarly in Beijing, China, green waste-dominated compost increased the total nitrogen and available phosphorus in soil, showing a favorable effect on strengthening soil microbial abundance albeit an insignificant influence on soil microbial diversity. The application of compost improved levels of soil organic matter content, pH, available phosphorus, and rapidly available potassium contents on bacterial communities in soil. [147]
- A study conducted in Kerala, India, showed that vermicomposting (worm composting)[148] increased the nutrient contents of compost, in particular nitrogen, phosphorus, and potassium, improving the quality of produce. It was also noted that the transition from chemical fertilizers to sustainable vermicomposting can happen in a short period of time, maintaining the yield efficiency. [149]

Water retention

- In two towns in Greece (Aliartos in Biotia and Kiourka in Attiki), all physical properties of the soils analyzed improved with the application of compost, in proportion to the compost rate. In particular, total porosity and saturated hydraulic conductivity, level of water content, retention ability, and aggregate stability were increased. [150]
- In Ile de France, France, both immature and mature composts increased aggregate stability by enhancing microbial activity and adding humified organic matter respectively.[151]

@Daun Moon

3.4.2.2. Composting for remediation of soil contamination

The widespread use of synthetic agricultural fertilizers has exposed farmers and communities to soil quality and contamination issues, as it has released large amounts of organic and inorganic pollutants into the soil. These include polycyclic aromatic hydrocarbons (PAHs), dibutyl phthalate (DBP), and di-n-octyl phthalate (DOP), and heavy metals such as cadmium and manganese.[152]

> *Composting is an effective solution, as it nurtures microbes, the key agents for degradation of organic contaminants in soil. In an experiment, it was shown that the application of compost also lowered concentration levels of heavy metals in soils such as lead, copper, and zinc.*[153]

The U.S. EPA also noted that composting is a cost-effective way to restore soils contaminated with toxic organic compounds (such as solvents and pesticides) and inorganic compounds (such as toxic metals).[154] According to the agency, hydrocarbons, a common industrial contaminant, degrade rapidly during the composting processes, and the addition of mature compost to contaminated soil accelerates plant and microbial degradation of organic contaminants. Moreover, mature compost also showed disease control effects on plants without the help of synthetic chemicals.[155]

3.4.2.3. Composting as a disaster prevention measure

Composting strengthens soil structures, increases the water-holding capacity of soil, and reduces stormwater runoff, which prevents soil erosion, floods, mudslides, and loss of food crops. The use of compost for reforestation further stabilizes soil. Compost is also commonly used as an erosion and sediment control method.[156] A compost blanket, a layer of compost applied on the soil surface as a mulch in disturbed areas, protects soil surfaces from wind and water erosion and conserves water.[157] Composting socks are mesh tubes filled with composted material. They are used to filter sediments, nutrients, bacteria, heavy metals, and petroleum oil residues in stormwater runoff; control erosion; and retain sediment in disturbed areas.[158] Similarly, composting berms act as a silt fence, controlling erosion and keeping sediment in place.[159]

3.4.2.4. Challenges

One of the major barriers to scaling up composting is the lack of institutional and financial support from municipalities.[160] Because short-term costs of composting can be higher than government-subsidized synthetic fertilizers, the compost market requires subsidies for stable compost production and application. Researchers observed that the constraints in applying compost are mainly economic, with technical or cultural factors playing a minor role, which could be effectively addressed by providing incentives to compost producers and farmers.[161]

Variable compost quality and toxics in compost could also pose a challenge to compost application. Immature compost can cause odors and develop toxic compounds after becoming anaerobic. When compost continues active decomposition, it can hamper plant growth due to reduced available oxygen and nitrogen, or the presence of phytotoxic compounds.[162] Toxic substances present in compost have been addressed by many researchers.[163] Certain composts were found to contain concentrations of metals including lead, cadmium, copper, and zinc, which are usually added by oils, solvents, and paper products found in the municipal waste stream.[164] Heavy metals and other toxic substances can potentially cause an adverse impact to biochemical processes essential for the growth of plants;[165] it is therefore recommended to use segregated food waste and yard waste for composting.[166]
In this context, the practice of using incineration ash as a soil additive raises concern. The guidelines on best available techniques and provisional guidance on best environmental practices of the Stockholm Convention notes that "Fly ash from electrostatic precipitators and residues from air pollution equipment almost certainly contain significant amounts of chemicals listed in Annex C of the Convention, so these wastes have to be disposed of in a controlled way."[167]

@United Workers

4. Additional benefits of zero waste

Chapter summary

- Well-implemented zero waste strategies offer a host of additional benefits beyond mitigation that can be especially attractive to cities.
- Environmental benefits: through waste reduction and phase-out of polluting waste management practices such as incineration, cities can reduce air pollution and toxic residues, save environmental resources, protect biodiversity, and improve soil quality.
- Economic benefits: cities can generate green jobs by expanding reuse, composting, and recycling; improve economic performance; achieve fiscal sustainability; and trigger innovative businesses.
- Social benefits: zero waste strategies enhance energy access and security by recovering material and generating energy; reduce poverty and inequality through the inclusion of waste pickers; contribute to agriculture with strengthened food and water security; improve public health; and reduce stressors such as noise, traffic, and congestion.
- Political and institutional benefits: the process of designing and implementing zero waste policies and programs involves collaboration between civil society, local authorities, and other stakeholders, which improves democratic quality of governance.
- The waste solutions at the top of the waste hierarchy have the greatest additional benefits, and score highest on emissions reductions.

4.1. Introduction

In a world beset by poverty, disease, conflict, and other interconnected maladies, the positive benefits related to the reduction of GHGs are more important than ever. Effective climate action will not only reduce GHG emissions, but also improve many of the most fundamental ways in which society functions through associated environmental, economic, social, and political and institutional benefits.

> *Focusing on these more tangible benefits is an opportunity to gain increased support from multiple constituencies, who can easily relate to issues that immediately impact their lives such as air quality, employment, food security, etc.*

Because climate change is partially the result of systemic problems not directly related to environmental degradation, solutions cannot just focus on the market or unilateral policies.[168] They need to be addressed from a systemic point of view that connects them to interrelated factors like poverty, gender inequality, corruption, conflict, and war.

> *Taking a particular climate action without an overall understanding of how mitigation, adaptation, and sustainable development actions interact and reinforce each other can be counterproductive and exacerbate the root causes of climate change.[169]*

Linkages across issues or problem areas reveal both the complexity of global environmental challenges, and potential opportunities.[170] Additional benefits of zero waste systems are an important reason to change waste management systems. In this way, pursuing climate policies focused on additional benefits can drive forward environmental policy in places that would otherwise find it challenging. For example, in many cities around the world, lack of political will, insufficient technical capacity, and competing priorities make it difficult for local governments to prioritize recycling. Much of the waste management work is therefore handled by the informal sector. In this context, waste reuse and recycling is often driven by economics (the monetary value that informal workers can extract from the waste they collect), rather than environmental or social policy itself.[171]

This chapter provides an overview of the additional benefits related to implementation of zero waste strategies, organized across four main categories: environmental, social, economic, and political-institutional. Taken together, they show clearly that the waste solutions at the top of the waste hierarchy have the greatest additional benefits, and also score highest on emissions reductions. These additional benefits include improving public health, reducing environmental pollution, incentivizing job creation, supporting community development, and addressing inequalities as well as various justice issues.[172]

4.2. Environmental benefits

Zero waste strategies deliver great additional environmental benefits, on top of reducing GHG emissions. They reduce air pollution and toxic residues, protect biodiversity and natural resources, reduce littering, and improve soil quality.

4.2.1. Reduction of air pollution and toxic waste

Zero waste ends the practice of burning waste, whether in the open, in dedicated incinerators, or in cement kilns as "alternative fuel," and dramatically reduces the quantity of waste sent to landfills. Burning and landfilling waste results in leachate leakage, water contamination, air pollution, and the spread of toxic ash.[173] Waste-to-energy incinerators and cement kilns are particularly significant sources of these harms.

Air pollution from waste disposal in incinerators and cement kilns increases the risk of cancer and other illnesses in local communities.[174] These emissions include lead, mercury, dioxins and furans, particulate matter, carbon monoxide, nitrogen oxides, acidic gasses (i.e., SOx, HCl), metals (cadmium, lead, mercury, chromium, arsenic, and beryllium), polychlorinated biphenyls (PCBs),[175] and brominated polyaromatic hydrocarbons (PAHs). Moreover, these polluting industries are often sited in low-income and marginalized communities,[176] with greater impacts on children,[177] which in turn burdens the care labor load of women, who tend to carry most of the child-rearing work.

Approximately 26 - 40% of waste becomes bottom ash, and the toxic residues from incineration, such as ash and wastewater, require special treatment and separate disposal.[178] However, they are mostly sent to landfills, where the ash can spread via wind and air; in some places, they are mixed into concrete, buried in salt mines, mixed into asphalt for roads, or even spread on agricultural lands, mislabeled as soil fertilizer.[179]

In Oporto, Portugal, environmental samples collected throughout several years showed that closing the incinerator greatly reduced air pollution levels in the area.[180] Similarly, a study in Seoul, Korea, observed an increased risk of asthma-related hospitalization in relation to a person's distance from an incinerator, and concluded that asthma should be considered an adverse health outcome during health impact assessments of incineration plants.[181] In this sense, it becomes clear that by reducing our reliance on these polluting practices, zero waste strategies such as waste reduction, organic waste prevention, source separation, and separate treatment alleviate the harm that incineration poses to human health and the environment.

4.2.2. Saving natural resources

Zero waste strategies like single-use plastic avoidance, reuse, refill, and recycling reduce demand for virgin materials. The extraction, transport, and processing of virgin materials produce high amounts of GHG emissions, consume high volumes of energy and water, deplete non-renewable resources, and destroy natural ecosystems. Recycling discarded materials such as aluminum or glass in particular provides industry with an alternative source of raw materials from which to make new products without the damage associated with virgin materials.

Similarly, recycling of paper and wood products reduces the demand for virgin wood fiber, thus reducing deforestation rates, which benefits the overall ecosystem. Some materials, like glass and aluminum, have relatively high recycling rates and can be recycled endlessly.[182] For this reason, it is estimated that 75% of the total aluminum ever produced is still in use today,[183] and that the recycling of aluminum reduces emissions by over 90% compared to primary production.[184] Successful recycling of these materials directly contributes to saving natural resources.

4.2.3. Protection of ecosystem health

Zero waste strategies have been demonstrated to achieve an important reduction of plastic waste in the environment, which significantly supports the overall health of ecosystems. In particular, plastic waste, which is often found to be the most leaked type of waste in the environment, severely contaminates biodiversity and the overall ecosystem balance.

From the approximately 6,300 million tonnes of plastic waste that has been generated globally as of 2015, only around 9% has been recycled and 12% incinerated. 79% has accumulated in dumps, landfills, lands, and waterways.[185]

> *While ocean plastic waste is most publicly prominent, further scientific research points to a wide spectrum of environmental, social, and economic impacts from plastic pollution throughout its life cycle.*[186]

Plastic pollution has not only been found in the marine environment but also in remote terrestrial locations, with growing evidence of plastic ingestion by organisms, including humans,[187] and contamination of the soil ecosystem.[188,189]

The plastic industry's continuing increase in plastic production and plastic waste generation is the most significant obstacle to solving the persistent problem of plastic waste.[190] Since the 1950s, global plastic production has grown by an average 9% per year, with a significantly increased production in the last two decades: half of all plastic ever manufactured has been made in the last 15 years.[191] It has been predicted that, unless the trends are reversed, production of plastic will double again over the next two decades.[192] This is why zero waste strategies that minimize plastic production and consumption, such as single-use plastic bans, reuse systems, or redesign solutions, are instrumental in reducing plastic in the environment and maintaining ecosystem health.


@Roman Synkevych

4.2.4. Improve soil quality

A key pillar in zero waste systems is the recovery of organic waste, which makes up the largest fraction of municipal solid waste and can easily be turned into compost on site, at decentralized, community-scale facilities or at larger, centralized facilities depending on local capacities and needs.

As discussed in the Adaption chapter, finished compost sent to gardens and farms returns organic matter and nutrients to the soil, improving its quality through boosting carbon sequestration capacity, increasing resistance to flood and drought, and reducing irrigation and tilling needs.[193] In this way, compost prevents desertification and land degradation, which impact mostly poor rural communities, small-scale farmers, women, youth, Indigenous peoples, and other at-risk groups. When compost replaces synthetic fertilizers,[194] the impact is even greater, saving energy and reducing emissions of nitrous oxide, a powerful GHG.[195]

4.3. **Economic benefits**

A zero waste strategy holds significant alignment between economic and environmental goals. This approach not only minimizes environmental harms, but is also significantly less expensive than systems that primarily burn or bury waste. It also contributes to a just society.

Zero waste systems offer more desirable employment opportunities than traditional waste management jobs, as they foster skills beyond basic manual labor, provide higher wages, offer more permanent positions, and improve quality of life. They also require a much lower initial capital investment in comparison to traditional industrial facilities, leading to better fiscal sustainability. Zero waste businesses have flourished across the world, triggering innovation and sustainability simultaneously.

4.3.1. **Job creation**

According to a recent global meta-analysis of the job creation potential of different waste management sectors,[196]

> *zero waste strategies score highest on environmental benefits and create the most jobs of any waste management approach:*
>
> - *Reuse creates over 200 times as many jobs as landfilling and incineration.*
> - *Recycling creates around 70 times as many jobs as landfilling and incineration.*
> - *Remanufacturing creates almost 30 times as many jobs as landfilling and incineration.*

The report analyzed the job growth potential of cities around the world if they were to divert 80% of recyclable and compostable waste from landfilling and incineration. The numbers were impressive: for example, Dar Es Salaam and Ho Chi Minh City could create over 18,000 jobs, and São Paulo could create an astonishing 36,000 new jobs.

The findings also discredit the common belief that waste management offers only low wages and undesirable jobs. Strong qualitative evidence of diverse, high-skill job creation through elements of zero waste programs was also observed. This evidence was reinforced by case studies that found that zero waste systems create large numbers of better-than-living wage jobs.[197]

This remarkable correlation demonstrates the compatibility of environmental and economic goals and positions the waste management sector as an opportune social infrastructure in which investments can strengthen local and global resilience.

For example, in San Francisco, the unionized and worker-owned waste management company Recology, which has achieved an 80% recovery rate,[198] offers a starting wage to waste collection drivers of USD 40 per hour, compared to the average California waste collection driver's income of USD 16 per hour.[199]

4.3.2. **Improved economic performance**

By switching to a zero waste strategy, municipalities can immediately begin reducing the costs of their waste management. A zero waste strategy is, essentially, good value for money.[200]

If a city is paying for a waste management service that only includes waste collection and disposal in a centralized facility like a landfill or incinerator, a switch to a zero waste system can be very beneficial. It avoids costs associated with transport, operating transfer stations, maintenance of sophisticated vehicles, leasing landfill space, and gate fees at the landfill or incinerator. In contrast to disposal facilities, there are potential revenues that can accrue from the sale of recyclables and compost.

For instance, the city of Parma,[201] Italy (population 196,518), has seen a €450,000 reduction in overall annual costs for waste management after introducing a zero waste system. In northern Italy, the cost of managing residual waste in 50 municipalities oriented to a zero waste strategy is €178.9 per household/year, compared to the average cost in Italy of €245.6 per household/year, representing 27% cost savings through zero waste.[202]

The city of San Fernando (population 306,659) in the Philippines has reduced the annual waste management budget by Php 36 million (594,745 EUR) after transitioning into a decentralized zero waste system.[203] The Philippine city of Tacloban (population 242,089), in turn, saved Php 21.6 million (348,065 EUR) in their annual budget after transitioning into zero waste, representing 27% cost reduction.[204]

In cities that have centralized and technology-driven waste management systems in place, one of the potential financial barriers to transitioning into a zero waste system is paying for the initial costs. Once set up, zero waste will be much more affordable than the conventional system, but overpaying for current waste management systems leaves cities without the resources needed to invest in new approaches. The Zero Waste Cities savings calculator[205] has been designed by GAIA member Ekologi brez meja[206] to help visualize and understand the financial benefits that adopting zero waste policies can bring to a local area.

@Santiago Vivacqua/GAIA

COUNTRY	MUNICIPALITY	DESCRIPTION	NUMBER OF JOBS CREATED PER 10,000 TONNES OF WASTE COLLECTED PER YEAR
SOUTH AFRICA	PretoriaTshwane	A private sorting facility has 240 direct employees involved in sorting, cleaning, and baling recyclables	**20 JOBS**
PHILIPPINES	The municipality of San Fernando	The city hired waste workers as collectors, drivers, segregators, Pstreet sweepers, and Material Recovery Facility managers for a landfill diversion program that began in 2012	**32 JOBS**
INDIA	Bangalore	Local social enterprise Hasiru Dala Innovations employs over 200 former waste pickers to provide door-to-door waste collection and education services, diverting 80% of what they collect from landfill	**304 JOBS**
INDIA	Goa	A company called VRecycle hires former waste pickers to offer recycling pickup, sorting, and education services	**140.9 JOBS**
ARGENTINA	Buenos Aires	12 cooperatives with over 6500 registered workers who work on collecting, sorting, washing, shredding, and compacting recyclables	**184 JOBS**
CHILE	The Peñalolén district of Santiago	Formally recognized former waste pickers provide door-to-door collection services of recyclables	**555 JOBS**
BRAZIL	Londrina	Waste pickers collect all waste types, as well as sort and bale recyclables	**302 JOBS**
BRAZIL	Dois Irmãos	Waste picker collective collects and sorts 100% of the city's waste, and pelletizes plastic	**288 JOBS**
BRAZIL	São Paulo	The YouGreen waste picker cooperative offers collection, sorting, and waste stream analysis services	**292 JOBS**

Source: www.no-burn.org/beyondrecovery

4.3.3. **Fiscal sustainability**

Conventional waste management approaches are often expensive propositions that are generally directly or indirectly funded by the public. Often, waste management is the single greatest line-item in many municipal budgets, despite much of the world's municipal waste remaining uncollected. Incinerators and engineered landfills require large investments to be built and maintained, often pushing municipalities into significant debt.

Waste-to-energy incineration is the most expensive waste management approach, three times the costs of landfills and up to five times the cost of recycling and composting.[207] A comprehensive study of the industry in the U.S., from its rise in the 1980's to today, concluded that incinerators are a bad investment for cities.[208] Construction and maintenance costs are significant and more capital-intensive compared to other forms of waste disposal. When an MSW incinerator has reached or is close to reaching its life expectancy, it requires another round of capital investment, often at the expense and risk of local taxpayers. Incineration revenue streams are volatile, dependent on competitive tipping fees and access to the renewable energy markets. Although larger plants provide economies of scale that may make profitability more secure, these oversize facilities require hauling and importing waste from a larger area, sometimes even different countries.[209]

Well-known examples of city bankruptcy due to investments in incinerators are the Harrisburg (Pennsylvania, USA) Incinerator,[210] and the Detroit incinerator (Michigan, USA).[211] Both were an ongoing source of contention due to toxic air emissions and unforeseen costs, which greatly contributed to the bankruptcy of these cities. The economic "lock-in effect" is caused by the fiscal debt incurred by the municipality to set up and run an incinerator, creating waste management systems locked into providing large amounts of waste as feedstock to incinerators that prevent development of sustainable policies, and essentially punish attempts to be less wasteful. This dynamic has also been reported in locations around the world, like Göteborg, Sweden,[212] Honolulu, USA[213] and the UK,[214] amongst others.

In contrast, this lock-in effect does not exist in zero waste systems, which, particularly in the Global South, tend to be decentralized and rely on local community-led collection, sorting, recycling, and composting infrastructure. Ideally, these systems are reinforced with waste reduction policies, although this is not widespread.

By implementing a better collection and recycling/composting system, municipalities can, on average, reduce waste management costs per tonne of waste by 70%.[215] Organics represent the largest component of global waste streams.[216] Organic waste prevention and source-separation, therefore, can greatly reduce the volume of material sent to landfills or incinerators. This in turn avoids the costly construction of new disposal infrastructure. When it comes to alternative treatment options, composting is cost-effective, has low start-up costs, and requires less land area than landfills.[217] In countries where governments are expanding waste services, the low cost of composting can free up funds for expanded waste collection coverage. Finished compost can also be sold to defray operational costs. Decentralized treatment can save further resources spent on collection, transportation fuel, and large infrastructure.[218]

@Petras Gagilas

4.3.4. **Innovative business development**

Zero waste business models have emerged in recent years, as businesses increasingly align their production and consumption models with the principles of waste avoidance and minimization. In particular, businesses that have replaced single-use packaging items and packaging in general have flourished, tapping into demand from a consumer base increasingly aware of the impacts of plastic waste.

Bans on wasteful products and packaging such as SUPs should therefore not be seen as detrimental to business because they create conditions conducive to new businesses. As opposed to multinationals, which depend heavily on plastic packaging, these new businesses are more likely to be local and to keep economic activity local as well.

In Europe, the packaging-free shop sector is growing rapidly, with an increasing number of shops, jobs, and sales turnover over the past five to ten years. Long-term forecasts present a mid-estimate EU market for bulk goods of €1.2 billion in 2030, with its best-case potential being significantly greater.[219]

This overlaps with characteristics and trends observed in circular economy businesses.[220] In both cases, they are defined in opposition to linear businesses, which are based on the paradigm of "take-make-waste."

Innovative ZW businesses - what do they look like? [221]

1. **A zero waste business is organized to recover high-quality materials post-consumption** i.e. used products and packaging like reusable cups or electronics. While linear businesses are not concerned with a product after it is sold, a zero waste business is designed to track it, so that the product can be easily taken back for reuse or to serve as feedstock in the production process. In this way, companies are also motivated to ensure the delivery of high-quality, long-lasting products designed for durability and reparability. Ensuring that the product can be repaired, upgraded, refurbished, remanufactured, or remarketed is an essential added-value. Examples of this model involve deposit return schemes (DRS) or leasing.

barePack: reusable containers for food meal deliveries in Singapore

barePack facilitates the purchase of food from restaurants in reusable containers through an app. It's a membership-based service that works across several delivery platforms like Foodpanda, Deliveroo, and Grab. The app shows restaurants that are enrolled in the network and reusable container options. Customers return the used containers to the restaurants, where they are cleaned and made ready to be used again.

2. **Zero waste businesses are made possible through collaboration along the supply chain**: while linear businesses are based on downstream cost-reduction and competitive relationships with suppliers, a zero waste business benefits from the joint work of all the actors along the supply chain, because the added value is the joint process of assembling and disassembling, delivering, and recovering. This is especially important for reusable packaging systems: collaboration amongst customers, businesses, staff, logistics providers, and the cities is key to success.[222] For example, online refillable/reusable delivery models offer an alternative to take-out SUP dining and operate in a closed-loop system of reuse and redistribution. Customers utilize these services by downloading sustainable apps to directly order food delivery, or to locate take-out restaurants that have sustainable container reuse and return models in place.

Refillables Hoi An: a packaging-free shop in Vietnam

Refillables Hoi An is the first refillable concept shop in Central Vietnam, founded by Alison Batchelor, a zero waste lifestyle practitioner who moved from Canada to Vietnam and missed the option of shopping in packaging-free shops in her new locale. The shop proposes an affordable packaging-free experience, targeting low-income families.

Its engagement with the community on increased waste prevention is also part of its value proposition: the founder has observed that suppliers are seeing increased patronage from startups; there are three different spots in Da Nang that are doing refills; and newly opened shops take their cue from Refillables Hoi An in terms of their product offer. Refillables Hoi An has a very strong alliance with suppliers, a critical collaboration to ensure both the minimization of plastic waste and affordable prices. Some of the suppliers have provided discounts on wholesale prices, which are facilitated by bulk purchases.

3. **Often, zero waste businesses sell a service rather than a product.** This development is also known as 'servitization' – providing access to products to satisfy user needs without needing to own physical products. These types of services are often run through local networks of similar businesses on a subscription or membership basis. Many companies have developed mobile apps or website maps to help customers identify participating businesses.

The Lavanda project by Eta Beta, Bologna (Italy)

The project provides a collection and washing service of used cloth diapers to the local community, in addition to delivering clean ones in return. Currently, the project works with public administrations, organizations, and cooperatives that manage nurseries. In the future, Lavanda wants to gradually open its services to families.

4. **Zero waste businesses are based on ecological and social values that complement overall business culture and philosophy.** Zero waste businesses are regenerative and restorative by design, keeping resources in use at their highest value for as long as possible; they also ensure socio-economic returns with better inclusive livelihoods, giving priority to local economies. These businesses seek to replace the linear economy based on a take-make-throw away model, which assumes our planet has infinite resources. In this sense, the value proposition of a zero waste business model is a direct engagement in improving the sustainability of the overall system, going beyond the conventional eco-consumerism.

Hasiru Dala in India: integration of waste pickers

Hasiru Dala works with a vision to integrate a generation of waste pickers into the mainstream circular economy. They aim to create better livelihoods for waste pickers through inclusive businesses that have an environmental impact. Their current services include the organization and provision of zero waste events where all SUP is replaced by compostable or recyclable options. They also provide brand owners with Extended Producer Responsibility (EPR) compliance.

4.4. **Social benefits**

4.4.1. **Enhanced energy access and security**

Within a zero waste system, the use of anaerobic digestion can offer an accessible source of energy when developed and implemented in a decentralized and community-led manner, improving energy security for local communities. Biogas derived from anaerobic digestion is a substitute for natural gas, providing a renewable energy source that can be deployed in sectors that are difficult to electrify. Yet caution should be given to implementation of AD, as explained in section 2.2.2.2.

Anaerobic digestion is a biological process wherein diverse groups of microorganisms convert complex organic matter into simple and stable end-products in the absence of oxygen. This process, which takes place in sealed vessels (anaerobic digesters), collects methane until it is burned as fuel, converting it into biogenic CO_2. In this sense, anaerobic digestion can be very attractive because it yields biogas, a mixture of methane and carbon dioxide that can be used as energy resources. Biogas can also be stored for timely conversion to electricity, which is useful in balancing fluctuating supply from intermittent renewables.[223]

AD of the organic fraction of municipal solid waste (OFMSW) is used in different regions worldwide to reduce the amount of material being landfilled, stabilize organic material before disposal in order to reduce future environmental impacts from air and water emissions, and recover energy. Advances and adoption of the technology are rapidly gaining momentum. Several research groups have developed anaerobic digestion processes using different organic substrates. Cheap, small-scale anaerobic digestion units have been employed with great success in remote communities with less-reliable access to energy grids in countries such as Bangladesh, India, and China.[224] In Kerala, where 70% of the waste is compostable organics, anaerobic digestion is an attractive option for energy generation from the putrescible fraction of MSW as well as for reducing the region's disposal problem.

4.4.2. **Reduction of poverty and inequality through the inclusion of waste pickers**

Despite the critical role the informal sector plays in waste management, waste pickers are often marginalized and live in extreme poverty.[225] Waste picking is poorly remunerated, dirty, and often demeaning work. Governments often ignore or actively discourage waste pickers' services, neglecting a potential route to increasing the reuse and recycling of waste.[226] As a result, many waste pickers face health risks and lack access to health care and other social protection.[227]

The inclusion of waste pickers is a fundamental pillar within zero waste systems, improving livelihoods and therefore reducing poverty and inequality, particularly amongst vulnerable women.

> *An analysis of 45 recent papers covering case studies on waste pickers from 27 different countries demonstrated that the integration of waste pickers into the formal sector can alleviate poverty by securing the livelihood of waste pickers and their families.*[228]

It also brings other societal benefits such as reducing child labor and gender inequality, as well as removing the stigma attached to this line of work. Other studies also recognize the importance of formal inclusion to generate income for waste pickers and economically empower women waste pickers; it can also contribute to the achievement of Sustainable Development Goals on eradicating poverty (SDG 1) and improving gender equality (SDG 5).[229]

The inclusion of waste pickers can help address these issues by offering formal recognition, involvement in municipal waste management decision-making processes, and access to facilities, which can provide dignity, personal safety, and increased earnings.

Successful integration of waste pickers

- In India, the integration of waste pickers into the formal system has proved invaluable to the sector. Hasiru Dala, an organization based in Bangalore, for example, worked with the local authority to issue formal identification cards to waste pickers. With the IDs, women were able to open bank accounts, hundreds of youth were able to get education loans, and families were able to access health insurance.
- In the Philippines, the waste workers who used to pick waste from the streets have been officially integrated into the zero waste program as formalized waste workers. This has allowed them to earn better wages under better working conditions.
- Malabon City, a highly-urbanized and densely populated city in Metro Manila, Philippines, implemented a city-wide zero waste program starting in 2017 to all the barangays (neighborhoods) in the city, many of which are now in advanced implementation. Waste pickers in Potrero, Malabon City used to earn about USD 20-40 a month from selling recyclable materials to junk shops; now they receive a monthly salary of USD 60 as a village waste worker, on top of what they earn selling recyclables collected from households.[230]

4.4.3. **Food and water security**

Both compost and biodigestate (an output from anaerobic digestion) have a beneficial impact for waste management and agriculture: by providing nutrients for soil, they increase soil fertility and its capacity to hold water, thus supporting food and water ecosystems.

Research shows that agroecological practices — like farm diversification, agroforestry, and organic agriculture — can make a significant contribution to helping low- and middle-income countries meet their climate adaptation and mitigation targets through their food systems;[231] the zero waste system can be a great ally to agroecology. The application of compost or biodigestate to soils supports urban and periurban agriculture, which in turn helps reduce the risk of flooding and the severity of drought, especially beneficial for small farmers and self-sufficient families.

The fact that, in many parts of the world, waste is primarily organic (over 50%) and that compost can play a major role in supporting the farming that feeds the world should lead to a market for compost. Challenges that currently prohibit this market are lack of support at the city level, reliance on government-subsidized fertilizer,[232] and lack of public awareness. Subsidies to enable composting and the use of organic waste in agriculture would be an effective measure to increase acceptance and demand.[233]

@Johnathan Nightingale

Success story from São Paulo

São Paulo is a great example of a city taking steps towards building bridges across zero waste, agroecology and sustainable food systems, while addressing inclusion and equity issues. The project Connect the Dots, an initiative from São Paulo's City Hall that won the grand prize of Bloomberg Philanthropies' 2016 Mayors Challenge in Latin America and the Caribbean, aims at creating a circular economy for food by supporting local and peri urban farmers to transition to organic agriculture. São Paulo municipality seeks to buy 30% of produce from small farmers for school meals to incentivise the transition.[234] In turn, organic farmers receive compost from a pilot composting facility in Lapa, which receives organic waste collected from around 50 street markets as well as garden waste. The composting facility can treat up to 60 tonnes of organic waste per week and produce approximately 900 tonnes of compost each year.[235] São Paulo also has a network of more than 50 local civil society organizations promoting the São Paulo Composta, Cultiva Campaign, asking the the São Paulo City Hall and City Council to increase its commitment to public policies for source separation and recycling of organic waste, and the promotion of agroecology in the municipality.[236] The local think-tank Instituto Pólis has put forward a comprehensive proposal to implement a segregated collection of organic waste and a community composting program prioritizing the participation of organizations of waste pickers.[237]

4.4.4. Better health outcomes

Because disposable items cause pollution throughout their lifecycle, a zero waste system will inevitably cut pollution and improve community health, especially for those living closer to these facilities. This has been comprehensively presented in point 4.2.1, under reduction of air pollution and toxic residues.

The widespread leakage of plastic in the environment and its persistence in the form of microplastic (<5 mm) has infiltrated the human food system, with increasing evidence that humans are eating plastic through food.[238, 239] The prevalence of toxics from plastic packaging and plastic waste in the food supply is leading to increased toxicity in our bodies and surrounding environment: recent studies have found these toxics in human blood and everywhere on the planet.

There are thousands of chemicals in food contact materials (FCM) that can potentially migrate into our food or drink, and eventually end up in our body. In Europe alone, some 8,000 chemicals can be used in food packaging and other FCM,[240] and many of the chemicals are carcinogens [241] and hormonal disruptors that are associated with higher incidences of cancer, infertility,[242] developmental disorders,[243] and immune disorders, with the costs related to neurodevelopmental disease and IQ loss reaching EUR 157 billion per year.[244] Women are exposed to higher risks of miscarriages, cancer, and further gender-related disparities, as these chemicals are commonly found in household and feminine hygiene products.[245]

4.4.5. Reduced stressors (noise, traffic, congestion)

Zero waste programs are able to reduce disamenities involved in waste disposal facilities, specially waste-to-energy incinerators. People living near incinerators and landfills complain of noise, litter, heavy vehicle traffic, odor, and air pollution. As temperatures rise in the summer, the smell often gets worse, forcing people to close their windows and avoid sitting outside. Areas with incinerators also experience greater vehicle traffic, with trucks bringing rubbish from other boroughs or counties. Operators often downplay these disamenities during the planning and permitting application stages, and when these problems do occur, these same operators will often dismiss them as inevitable or unavoidable.

@Oren Langelle

4.5. Political and institutional benefits: improved democratic quality of governance

Some of the most successful zero waste systems have been led by collaborations between civil society, local authorities, and governments, bringing together a wide range of stakeholders to build a political and visionary common ground that strengthens the quality of governance itself.

In these cases, communities took part in the design of the plan, or there was a significant initial consultation process. This paid off with better design and higher participation rates, since programs were tailored to community members' specific needs and context. Residents were therefore more active in consuming sustainably, minimizing waste, separating discards, and composting at home. They were also more active in monitoring the implementation of the programs in their community, in collaboration with the local authorities.

For example, in Thiruvananthapuram (India), young volunteers who call themselves Green Army International have been instrumental in the implementation of the Green Protocol, a government initiative to eradicate single-use plastic from public events.

Inclusive zero waste systems ensure that resource recovery programs include and respect the community and all social actors involved in resource conservation, especially informal recyclers whose livelihoods depend on discarded materials. The workers who handle waste are fully integrated into the design, implementation, and monitoring processes, as it is the application of their skills and efforts that ultimately make the system function. A successful zero waste system prioritizes waste workers' safety and well-being and ensures that their interests are aligned with programmatic success. In some communities, where informal recyclers come from historically excluded populations, this may require ending long-standing discriminatory practices.

Stressors from waste-to-energy incinerators [246]

In the UK, residents in areas hosting waste facilities have raised serious complaints of noise, odor, and other types of disturbances. The cases include daily noises lasting 2-3 minutes each time and disturbing vibrations from cargo trains for waste transportation in Runcorn, which led to a protest by 100 residents in 2015;[247] and reported odors of rotting food and growing number of flies, which forced residents to keep their windows closed in Derby.[248] Residents in Detroit, U.S.A., suffered for decades from strong odors of rotten eggs and rotting garbage coming from an incinerator with over 20 odor violation records, until the facility was shut down in 2019.[249]

Incinerators also depend on large, heavy-duty diesel trucks for waste hauling, which emit hazardous air pollutants and cause loud noises and traffic congestion.[250]

@Rommel Cabrera/GAIA

5. Case studies

5.1. Introduction

5.1.1. Background

The case studies below offer a snapshot of what zero waste could look like, and the GHG emissions mitigation impact, in a variety of cities. While the principles of zero waste are universal, the implementation will vary widely from place to place, based on a host of local factors. The cities included in this report were selected to represent a wide range of conditions. They are megacities and small-to mid-sized communities; cities with ample waste management budgets and some that struggle to collect the waste generated; a variety of climatic conditions; cities with a robust informal sector, and those without; cities with highly centralized waste management systems, and those with many private and public actors; cities that are growing rapidly, growing slowly, and even one whose population is expected to shrink.

One thing that all these cities have in common is the presence of an active GAIA member organization that is eager to partner with local governments to bring about a transformation in waste management. Most of them are implementing successful pilot zero waste projects that can be scaled up with government support. These organizations played a critical role in obtaining, analyzing, and translating the data that underlie the GHG analyses. The zero waste scenarios depicted in the case studies are drawn from their visions for their own cities.

5.1.2. Modeling zero waste

To calculate the GHG emissions from the waste system, we used the 'Carbon Calculator for Zero Waste Projects' developed by inédit for the Mission Zero Academy. This tool compares a baseline and an alternative scenario to determine the change in overall GHG emissions associated with the waste system. A particular feature of this tool is its ability to analyze the emissions of reducing waste generation. For more details, see the Data and Methods Appendix.

The year 2030 has been identified by the Global Methane Assessment as an important target for rapid climate action. Past experience has shown that waste management systems can dramatically transform in this short a time. For each city, we created a baseline, or business-as-usual scenario, and a zero waste alternative scenario ('road-to-zero-waste'). Both scenarios used the same population, waste generation, and waste composition inputs. The zero waste scenario differs from the baseline in two important aspects, and the resulting changes in GHG emissions reflect only these two changes:

1. **the use of waste minimization strategies to reduce the generation of targeted waste streams** (particularly single-use plastic and, in the case of Bandung, food waste). These scenarios are city-specific and based upon plans or proposals that already exist in each city
2. **efforts to divert waste material to beneficial uses, such as compost and recycling**. We projected 80% diversion rates for easy-to-recycle material categories (organics, metals, glass, paper, cardboard, and wood), and 15% diversion rates for hard-to-recycle materials (plastic, textiles). These produced overall diversion rates between 42% and 68%.

@Rommel Cabrera/GAIA

Past experience has indicated that cities can reach 80% or higher rates of waste diversion within just a few years (see Section 2.1). Our modeled scenarios are thus conservative and fall well short of what is technically and economically feasible within the 2030 timeframe.

The zero waste scenarios modeled in this report do not represent an end point or ultimate goal for waste management; rather, they represent a conservative estimate for a waste system undergoing transformation, and a 2030 milestone along that path. Results are thus indicative of moderately ambitious programs. Deeper emissions cuts can be expected from more ambitious zero waste implementation.

5.2. City-level case studies

- 5.2.1. **Lviv, Ukraine**
- 5.2.2. **Dar es Salaam, Tanzania**
- 5.2.3. **Temuco, Chile**
- 5.2.4. **São Paulo, Brazil**
- 5.2.5. **eThekwini (Durban), South Africa**
- 5.2.6. **Seoul, South Korea**
- 5.2.7. **Bandung, Indonesia**
- 5.2.8. **Detroit, USA**

Lviv, Ukraine

GHG reduction potential in Road-to-ZW scenario: 93%

@Max Bashyrov

Key statistics (2021)

- **Population: 783,065**
- **Total municipal solid waste generation: 238,965.63 tonnes/year**
- **Per capita waste generation: 0.84 kg/day**
- **Waste collection: 11% separation collection**
- **Waste diversion rate: 11%**

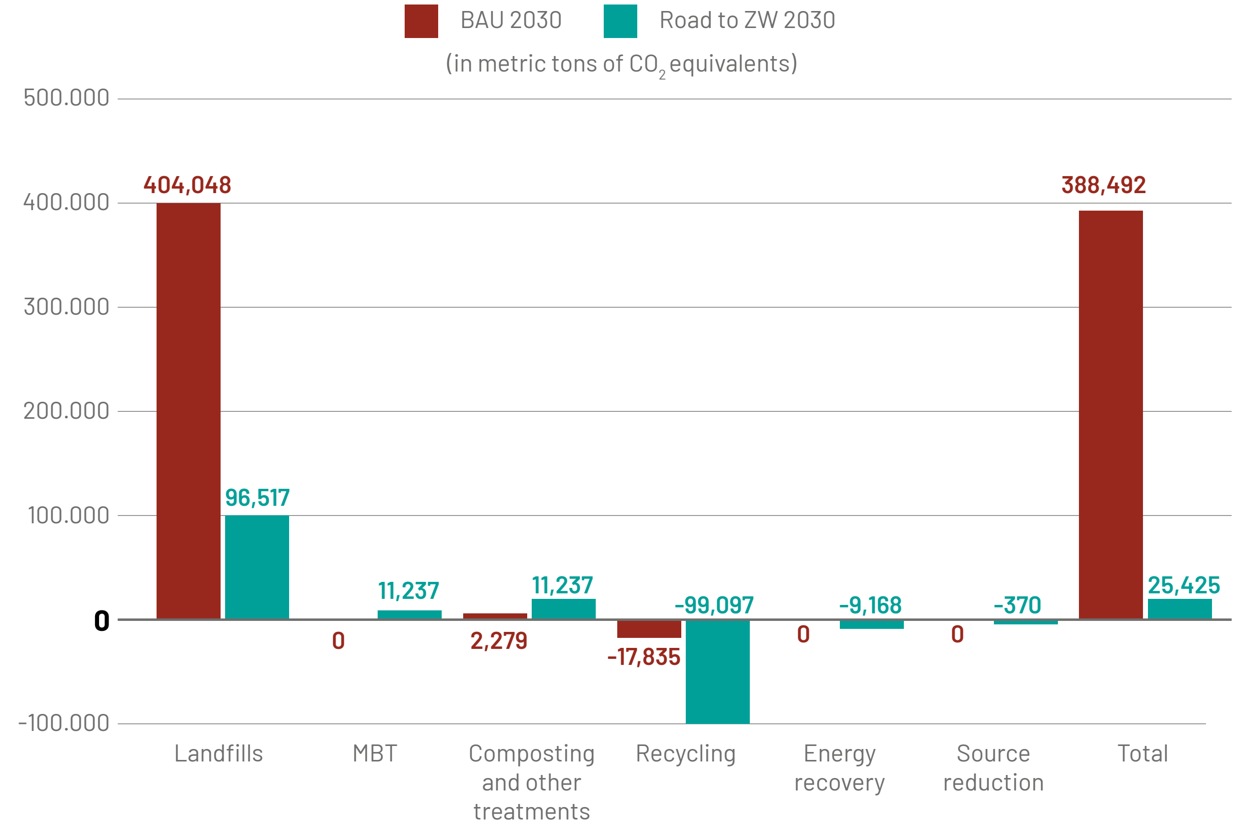
Lviv is the cultural, economic, and business center of Western Ukraine. With a population of 783,065, more than 2.5 million tourists visiting each year, and a growing number of Information Technology companies making homes in the City, Lviv's waste toll is on the rise. Single-use items and organic waste from touristic sites, and increased amounts of e-waste add challenges to a Medieval downtown not equipped to organize waste collection. The Russian war in Ukraine also made Lviv the major shelter for refugees and hub for humanitarian aid as well, adding an enormous amount to its waste footprint.

As with other cities in Ukraine, Lviv lacked a sound waste collection and recovery system. A major fire that took place in Lviv Grybovychi Landfill in May 2016, however, changed how the city looked at its waste problem. The landfill was permanently closed after the fire took four lives, which prompted the city to commit to becoming a zero waste city due to the high cost of sending waste to other cities' or regional landfills. The tragedy brought political and public attention to waste management and sparked a reform in the waste sector.

As the first non-EU city to participate in the *Zero Waste Cities certification program*, the Lviv government is making moves to improve its waste management system; in September 2020, the City instituted source-separated collection for organics, with a goal to divert 80% of kitchen waste and 100% green waste. Together with waste management companies, recyclables wholesalers and informal waste pickers, Lviv aims to increase separate collection of recyclable materials and implement pilot EPR schemes. The City plans to replace single-use tableware and food takeout boxes with reusables and establish a network of drinking fountains in public places. Lviv is also pioneering an effort to replace sanitary products, such as diapers and menstrual products, with reusable equivalents. Special emphasis is put on repair and refurbishing businesses especially for electronic and electric appliances, apparel and footwear, accessories, and furniture. However, the plan also raises concerns by including a construction project for an MBT plant, which will produce refuse-derived fuel to be burned in cement kilns by 2024.

Lviv in 2030 – Business as Usual vs. Road to Zero Waste

The below chart shows estimates for annual GHG emissions associated with waste management in Lviv by 2030 in two scenarios: 1) Business as Usual (BAU) based on the data from 2021, and 2) Road to Zero Waste based on consultations with local groups including Zero Waste Lviv. Assumptions that informed each scenario are detailed in the table below.



Treatment	BAU 2030	Road-to-ZW 2030
Landfill	297,433 tonnes of municipal solid waste landfilled The source of all GHG emissions in Lviv's waste system	158,480 tonnes of municipal solid waste landfilled (47% reduction). Landfill gas emissions drop by 76% but are still the largest emissions source
Incineration	none	none
Composting & other treatments	10,431 tonnes of organic waste is composted	104,190 tonnes of organic waste is composted and 158,480 tonnes of residuals are sent to MRBT
Recycling	26,708 tonnes through voluntary efforts	71,271 tonnes, a 2.7 times increase, through source separation. This results in GHG reductions greater than the total landfill emissions
Energy recovery	none	none
Source reduction	none	Voluntary programs avoid 310 tonnes of plastic waste
Overall diversion rate	11%	67%

GHG reduction potential in Road-to-ZW scenario: 93%

Key takeaways

1 Currently, the biggest source of GHG emissions in Lviv is methane from landfilled organic waste, as most waste is sent to a landfill, with minimal efforts at recycling or composting.

2 In the Road to Zero Waste scenario, **Lviv would achieve an increase in overall diversion rate from 11% to 67%, avoiding annual GHG emissions by 63,910 tonnes CO_2e in 2030.**

3 **This approach would reduce annual residual waste by 47%, landfill methane emissions by 76%, and overall GHG emissions by 93%, compared to the Business as Usual 2030 scenario.**

4 The Road to Zero Waste scenario includes diverting 80% of organic waste from landfills through composting, recycling (80% of paper, cardboard, glass, and metal, 15% of plastic and textiles, and 1.5% of electronics and other), moderate SUP bans, and avoiding incineration.

5 Grassroots organizations including Zero Waste Lviv assure the city that the Road to Zero Waste can be achieved through joint efforts of the city council, citizens including marginalized waste pickers, businesses, NGOs, and social entrepreneurs.

Recommendations

- **Continue with the separate collection of organic waste and composting.**
- **Ban single-use plastic.** Continue and expand bans on single-use items such as bags, cups, bottles, to-go containers, cutlery, etc.
- **Provide incentives for hotels, restaurants, and cafés to set up reusable cups, tableware, packaging for drinks and food, to-go and deliveries, and festivals.**
- **Promote the tap water and water fountains in public area to reduce the use of bottled water.**
- **Promote packaging-free shelves in supermarkets and outdoor markets and bring-your-own systems (BYO).**
- **Develop a program on reusable nappies, early potty training, reusable menstrual products.**
- **Financial support program support for repair businesses, local second-hand stores and markets, and other facets of the sharing economy**

@Andriana Syvanych

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Written by: Iryna Myronova. This case study was prepared as part of the report, "Zero Waste to Zero Emissions: How Reducing Waste is a Climate Gamechanger (GAIA, 2022)." Please visit www.no-burn.org/zerowaste-zero-emissions to access the full report and detailed notes on data and methods.

Dar es Salaam, Tanzania

GHG reduction potential in Road-to-ZW scenario: 65%

@Peter Mitchell

Key statistics (2017)

- **Population: 5,200,000**
- **Total municipal solid waste generation: 1,679,000 tonnes/year**
- **Per capita waste generation: 0.9 kg/day**
- **Waste collection: 40% collection rate (no statistics for separation)**
- **Waste diversion rate: no statistics**

Dar es Salaam is the third fastest growing city in Africa and the ninth fastest growing in the world, with a population projected to be nearly 11 million by 2030. The growth of urbanization, industrialization, and population in Dar es Salaam city has increased the solid waste generation rate.

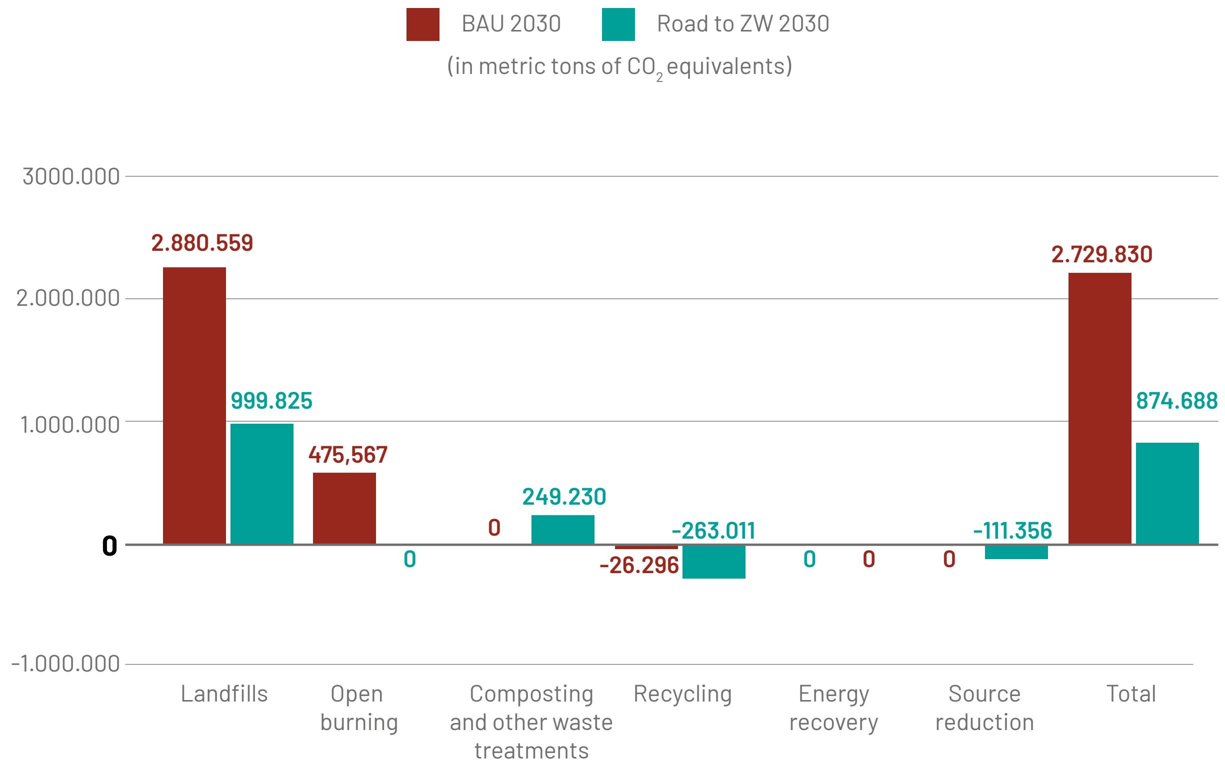
Poor waste collection, lack of reliable disposal sites, inadequate solid waste infrastructure, and insufficient guidelines on waste separation at source are among the major challenges in the waste sector. The city generates an estimated 5,600 tonnes of solid waste daily, and only between 900 and 1,500 tonnes are taken to the dumpsite by the city. The waste is transported and dumped at the only official dumpsite, Pugu-Kinyamwezi, which does not have gas collection or other mitigation measures. The rest of the waste is dumped onto vacant land or waterways, and much is burned in the open.

In Dar Es Salaam, recycling is currently spearheaded by the efforts of an informal army of self-employed, micro-entrepreneurial waste pickers. According to the Tanzania Investment Guide on Waste Management 2020, a total of 15 informal recycling transfer stations and one official government-managed dumpsite are mapped out across the city, supporting the operations of approximately 1,237 waste pickers. Waste pickers collect recyclables from houses and streets and work at the dumpsite as well, collecting an average of 20 kilograms per day.

Nipe Fagio, a local group that has been building cooperative-led zero waste systems in Dar es Salaam since 2019, sees great potential in formation and formalization of waste collection cooperatives in reducing the city's waste and carbon footprint. As an example, Wakusanya Taka Bonyokwa Cooperative Society's contribution to separate collection helped to divert more than 80% of the waste generated in a low-income sub-ward of Bonyokwa, in the Ilala district in Dar es Salaam through composting, reuse, and recycling, reducing the waste to 10-20%.

Dar es Salaam in 2030 — Business as Usual vs. Road to Zero Waste

The below chart shows estimates for annual GHG emissions associated with waste management in eThekwini by 2030 in two scenarios: 1) Business as Usual (BAU) based on the data from 2016, and 2) Road to Zero Waste based on consultations with local groups including Nipe Fagio. Assumptions that informed each scenario are detailed in the table below.



Treatment	BAU 2030	Road-to-ZW 2030
Landfill (dumpsites)	2,739,300 tonnes of municipal solid waste disposed, including open burning and open dumping	1,123,481 tonnes of municipal solid waste. Open burning is ended. Landfill gas emissions drop by 47%
Incineration	Open burning is prevalent; we estimate 508,023 tonnes CO_2e	none
Composting & other treatments	none	1,192,801 tonnes composted
Recycling	Informal sector active but no data available	423,018 tonnes recycled, resulting in 371,654 tonnes CO_2e reduction
Energy recovery	none	none
Source reduction	none	Single-use plastic bans reduce plastic waste by 129,514 tonnes, resulting in 111,356 tonnes CO_2e avoided (a 35% reduction in total plastic waste generation)
Overall diversion rate	0%	53%

GHG reduction potential in Road-to-ZW scenario: 65%

Key takeaways

1 The biggest portion of GHG emissions in Dar es Salaam is methane emissions from organic waste in dumpsites, due to the lack of proper organic waste management systems, such as separate organic waste collection and composting, despite the high amount of organic waste generated (49% of the total municipal solid waste, 39% kitchen waste and 10% grass and wood).

2 In the Road to Zero Waste scenario, **Dar es Salaam would achieve an increase in overall diversion rate from 0% to 53%, avoiding annual GHG emissions by 1,889,583 tonnes CO_2e in 2030.**

3 **This approach would reduce annual residual waste by 59%, landfill methane emissions by 47%, and overall GHG emissions by 65%, compared to the Business as Usual 2030 scenario**. More than two thirds of this reduction would come from reduced landfill methane emissions, and another quarter from ending open burning.

4 The Road to Zero Waste scenario includes 80% diversion rates for organics, paper, cardboard, glass, and metal, and 15% for plastic, textiles, and electronics, ending open burning, banning single-use plastic (except for sanitary uses, such as diapers, and clear PET bottles, which are part of an existing recycling economy). Organic waste would be managed in a network of neighborhood-level composting stations, of which pilots already exist.

5 Nipe Fagio has been working assiduously in the waste sector for many years, and envisions a road-to-zero-waste future built together by waste pickers who have long been playing a critical role in capturing the value of discarded materials in Dar es Salaam.

Recommendations

- **Stop open burning**. The city must prevent waste from being burned in the open by all means, as it generates GHG emissions in addition to posing risks to the environment and public health.
- **Ban most single-use plastic**. Tanzania has already put in place regulations to stop producing, transporting, selling, and using single-use plastic carrier bags, straws, and plastic seals, and is establishing extended producer responsibility regulations. With strong political will and the ongoing Single-Use Plastic Free East African Community campaign, the city can further reduce plastic waste through more stringent regulations.
- **Integrate waste pickers into the waste management sector**. The city supports waste pickers for their waste collection and material recovery efforts, by providing adequate equipment, infrastructure, and certification support. The City should also support grassroots organizations and educational programs in their efforts to train residents on effective waste reduction practices.
- **Support the integration of waste cooperatives into the waste management sector**. The layout of the city, especially in unplanned low-income neighborhoods, make it difficult for waste collection vehicles to reach households. Waste cooperatives can have an essential role in door-to-door collection with the enforcement of segregation at source, servicing areas that have been historically offgrid.
- **Implement segregation of waste at source linked to segregated waste collection**. Segregation of waste at source, when combined with collection systems for segregated waste, increase composting and recycling rates, resulting in significant rates of waste recovery.

@Chris Morgan

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Written by: Ana Lê Rocha. This case study was prepared as part of the report, "Zero Waste to Zero Emissions: How Reducing Waste is a Climate Gamechanger (GAIA, 2022)." Please visit www.no-burn.org/zerowaste-zero-emissions to access the full report and detailed notes on data and methods.

Temuco, Chile

GHG reduction potential in Road-to-ZW scenario: 73%

@Patricio Saavedra Poblete

Key statistics (2017)

- **Population: 302,931**
- **Total municipal solid waste generation: 298 tonnes per day (including residential and commercial waste)**
- **Per capita waste generation: 0.98 kg/day**
- **Municipal waste collection system:**
  - 100% collection rate (97.8 % landfill)
  - Minimal separate collection
- **Citywide recycling rate: 2% overall**

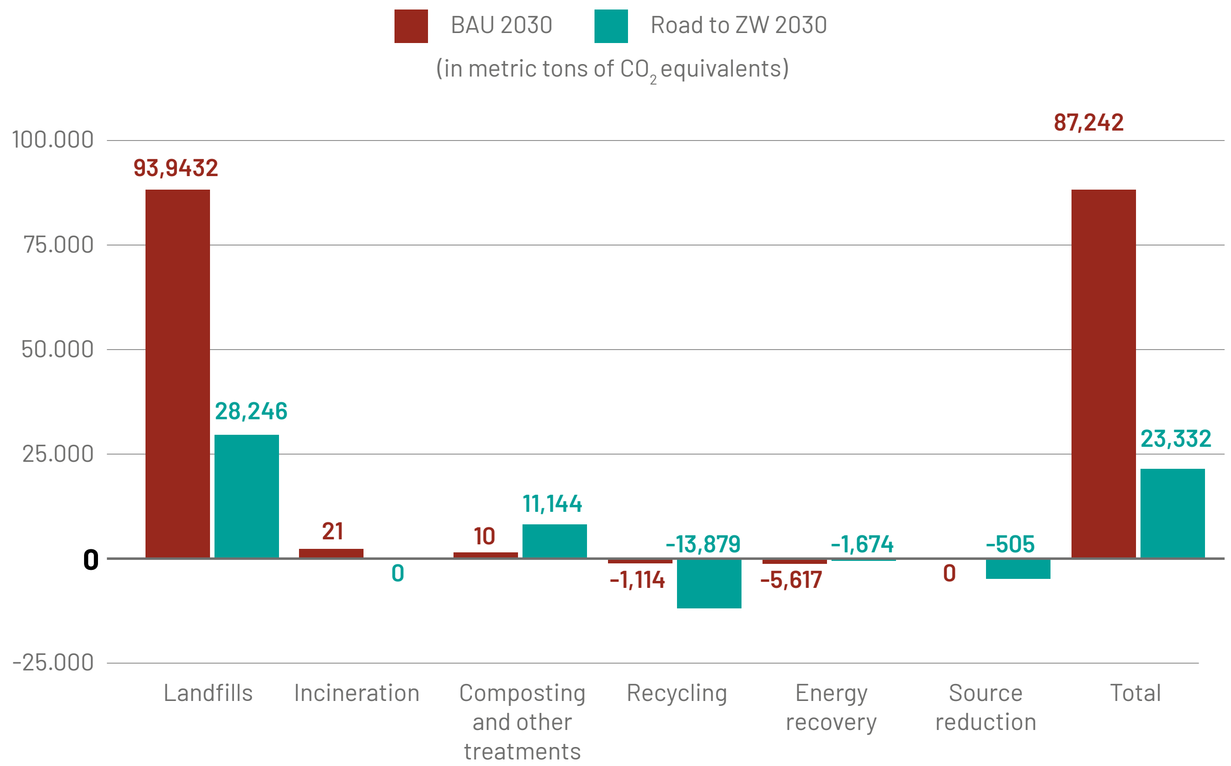
The City of Temuco is situated in the Araucanía Region of southern Chile, one of the poorest regions in the country. A third of its population is of Mapuche indigenous heritage, who have, over the decades, been confronted with numerous economic and environmental injustices. In the early 90s, the Chilean government began siting numerous landfills within their territory as a means to manage the country's ever-growing waste streams, which led local communities to campaign against the landfill and wastewater-induced contamination of their lands.

Other than a small pilot program, Temuco does not have a separate collection system for its recyclables or organic materials, so the municipality collects all waste unsorted. These materials get transported to a transfer station about 25 km away from the city, and then disposed of in the Laguna Verde landfill, located in Los Angeles city, 190 km away from Temuco, posing strong economic and environmental burdens on the city from high transportation costs and carbon emissions. Both the transfer station and the landfill are operated by private companies - GERSA and KDM Industrial, respectively. A small amount of waste is incinerated in a cement plant. To mitigate the increased cost of shipping its waste outside of the city, the municipality of Temuco attempted to have an incinerator built in the community, but failed to do so as a result of concerted community resistance, including the creation of a neighbrohood zero waste pilot project.

Based on data from 2018, the city recycles only 2% of its waste, mostly glass (1.6%), as well as marginal amounts of other mixed recyclables, through so-called "green points," which are public containers where people can take their recyclables and which private companies collect from. Since 2019, the municipality has also distributed 3,600 compost bins to residents across the city, and currently estimates that 1,576 tonnes of organic waste are being recovered annually. This is a step toward having a municipal organics diversion program in Temuco, but the municipality has yet to take further systemic action. There is also a municipal pilot program of separate collection of PET plastic bottles and cardboard boxes in one neighborhood, but much of the city's recycling is carried out by the hundreds of waste pickers that operate within its borders, so the actual recycling figures should be higher than the official ones. There used to be more than ten organizations representing these workers, but there are now only two surviving ones - Proyecto Andes and Mujeres Emprendedoras de Vista Verde.

Temuco in 2030 – Business as Usual vs. Road to Zero Waste

The below chart shows estimates for annual GHG emissions associated with waste management in Temuco by 2030 in two scenarios: 1) Business as Usual (BAU) based on the data from 2018, and 2) Road to Zero Waste based on consultations with local groups including Red de Acción por los Derechos Ambientales (RADA). Assumptions that informed each scenario are detailed in the table below.



Treatment	BAU 2030	Road-to-ZW 2030
Landfill	123,462 tonnes of municipal solid waste landfilled per year. Landfill gas represents virtually all emissions	50,073 tonnes of municipal solid waste landfilled per year, a reduction of 59%
Incineration	A small amount is sent to cement kilns	No incineration of waste
Composting & other treatments	negligible	80% (or 60,871 tonnes) of organic waste is composted
Recycling	Minimal recycling	80% of paper, cardboard, glass and metal, and 15% of plastic, textiles and electronics recycled (totalling 16,843 tonnes)
Energy recovery	Landfill gas is currently flared with no energy recovery; a minimal amount is recovered via cement kilns.	Landfill gas is flared without energy recovery
Source reduction	No program	A ban on single-use plastic in eating establishments would eliminate 587 tonnes of plastic per year
Overall diversion rate	2%	55%

GHG reduction potential in Road-to-ZW scenario: 65%

Key takeaways

1 Currently, the biggest source of GHG emissions in Temuco is methane from landfilled organic waste, as all waste is sent to a landfill, with minimal efforts at recycling or waste diversion.

2 In the Road to Zero Waste scenario, **Temuco would achieve an increase in overall diversion rate from 2% to 55%, avoiding annual GHG emissions by 63,910 tonnes CO_2e in 2030.**

3 **This approach would reduce annual residual waste by 59%, landfill methane emissions by 70%, and overall GHG emissions by 73%, compared to the Business as Usual 2030 scenario**.

4 The Road to Zero Waste scenario includes diverting 80% of organic waste from landfills through composting, recycling (80% of paper, cardboard, glass, and metal and 15% of plastic, textiles and electronics), moderate SUP bans, and no incineration.

5 Informal recyclers play a critical role in recycling in Temuco, and the city has yet to support recognize and support the grassroots efforts. Community groups continue to advocate for the municipality to become an ally and partner in their efforts toward a zero waste city.

Recommendations

- **Organics**, which constitute at least 60% of the total waste generated in Temuco, should be managed mainly through a municipal composting program put in place and managed by the city.
- **Recyclables** (glass, paper, cardboard, metals, plastics # 1-PET and 2-HDPE), which represent approximately 22.5% of the total waste stream, should be separated and collected door-to-door by the city so they can sell the materials to end-markets for processing.
- **Single-use plastic** (SUP) used for food and beverage products is being regulated by Chile's Law NO. 21.368 (August 2021) with weak enforcement. SUP should be reduced through promotion of reusable containers. Local groups would like to see a city ordinance to codify the use of reusables. They would also like to have access to more provisions for buying in bulk, in order to move away from the throwaway culture. Deeper SUP cuts should also be enacted.
- **A Food Bank** system should be set in place and used as an avenue to redistribute food to low-income communities and to prevent leftover food from restaurants, greengrocers, bakeries, etc. from going to waste.
- **Waste pickers** should be supported by the municipality in their material gathering efforts by being provided with adequate equipment, infrastructure, and certification support, so that they can effectively compete with commercial recyclers. The city should also support grassroots organizations and educational programs in their efforts to train residents on effective waste reduction practices.
- **Residual materials** (which would constitute **30% or less** of the waste stream once zero waste measures are in place) should be disposed of in a sanitary landfill, a system that is currently in place outside of Temuco.

@ Jose Luis Vargas

gaia

Written by: Cat Diggs and Alejandra Parra Muñoz. This case study was prepared as part of the report, "Zero Waste to Zero Emissions: How Reducing Waste is a Climate Gamechanger (GAIA, 2022)." Please visit www.no-burn.org/zerowaste-zero-emissions to access the full report and detailed notes on data and methods.

São Paulo, Brazil

GHG reduction potential in Road-to-ZW scenario: 105%

@Rodrigo Canisella Fávero

Key statistics (2020)

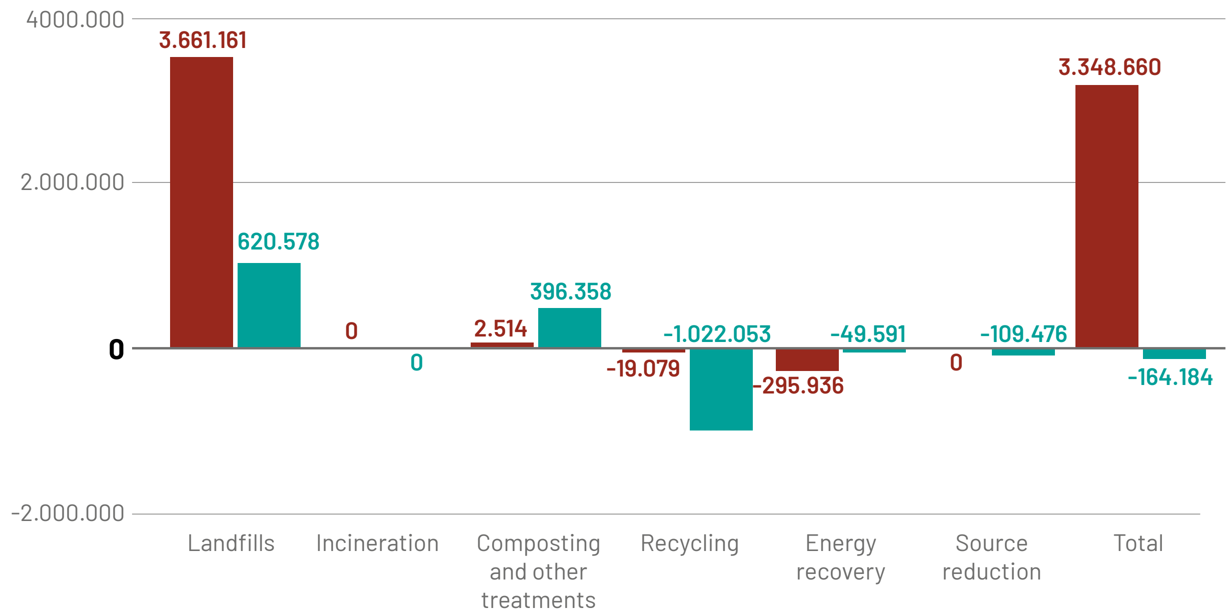
- **Population: 11,869,860**
- **Total municipal solid waste generation: 3,882,430 tonnes per year**
- **Per capita waste generation: 0.9 kg/day**
- **Waste collection system: minimal official separate collection, no official monitoring of informal recycling**
- **Waste diversion rate: 1% excluding informal recycling**

One of the largest cities in the world, São Paulo had a population of nearly 12 million people in 2020, a figure that is expected to grow by another half million people by 2030. The city relies almost exclusively on landfilling to manage its waste, with 99% of the waste officially tracked by the city going to landfills. An organized community of waste pickers and waste picker collectives recover a large share of recyclable materials, but this flow is poorly tracked by the city and not included in official estimates. This is reflected in the low recovery rates noted in the business as usual scenario for this analysis. Organics, which comprise half of the city's waste stream, have no informal recovery market, and are almost exclusively sent to landfill along with the rest of the mixed municipal waste collected by the city.

To improve overall material recovery rates and address the high levels of organic waste, the city has put forth a plan to greatly increase its mechanical-biological treatment (MBT) capacity to treat all of the city's mixed municipal waste. Unfortunately for the plan, it is not feasible for the city to scale up MBT capacity quickly enough to process all municipal waste by 2030, nor is it possible for MBT alone to achieve the target recovery rates for recyclables that the city has set in the Climate Action Plan (34% of paper and cardboard, 25% of plastic). Instead, waste pickers and advocates at citizen organization Pólis Institute have proposed an alternative scenario that integrates existing waste picker expertise and networks to institute separate collection for recyclables and organics, and divert materials from landfill to composting and recycling. This would be complemented by a ban on certain single-use plastic, greatly reducing the amount of waste sent to landfill without costly investments in MBT facilities.

São Paulo in 2030 — Business as Usual vs. Road to Zero Waste

The below chart shows estimates for annual GHG emissions associated with waste management in São Paulo by 2030 in two scenarios: 1) Business as Usual (BAU) based on the data from 2019, and 2) Road to Zero Waste based on consultations with local groups including Pólis Institute. Assumptions that informed each scenario are detailed in the table below.



Treatment	BAU 2030	Road-to-ZW 2030
Landfill	4,334,595 tonnes of municipal solid waste per year	1,939,677 tonnes of municipal solid waste per year (55% reduction)
Incineration	none	none
Composting & other treatments	none	1,723,724 tonnes of organics composted per year and 1,939,677 tonnes per year of residuals are processed with MRBT
Recycling	Significant informal sector recycling escapes formal data collection	Expanded informal sector role captures an additional 715,980 tonnes of dry recyclables per year
Energy recovery	Landfill gas is captured and flared without energy recovery	Landfill gas is captured and flared without energy recovery
Source reduction	none	127,327 tonnes of plastic packaging are avoided through a single-use plastic ban
Overall diversion rate	1%	68%

GHG reduction potential in Road-to-ZW scenario: 105%

Key takeaways

1 As organics make up half of São Paulo's waste stream and separate collection and treatment for organic waste is almost non-existent, methane emissions from organic waste in landfills are the primary source of GHG emissions in São Paulo.

2 In the Road to Zero Waste scenario, **São Paulo would achieve an increase in overall diversion rate from 1% to 68%, avoiding annual GHG emissions by 3,512,844 tonnes CO_2e in 2030.**

3 **This approach would reduce annual residual waste by 55%, landfill methane emissions by 83%, and overall GHG emissions by 105%, compared to the Business as Usual 2030 scenario; the waste system will be transformed into a net-negative sector.**

4 The Road to Zero Waste scenario includes diverting 80% of organic waste from landfills, increasing recycling rates by integrating waste pickers and separate collection, and implementing a single-use plastic ban.

5 The city's proposed plan to address waste sector emissions and achieve its recovery rate goals solely through MBT is infeasible; instead, improving organic waste treatment and strengthening recycling efforts led by organized waste pickers would greatly increase the city's municipal solid waste diversion.

Recommendations

- **Waste picker** integration can draw on the expertise of informal waste workers to expand current informal recycling efforts, which account for the majority of recycling in the city, and achieve the city's target recovery rates for certain recyclable materials without costly investments in MBT infrastructure.
- For **organic waste**, which makes up half of São Paulo's waste stream but has no commercial value, waste pickers and other actors would need to be financed to separately collect it and divert it from landfill to composting to achieve the large GHGs emissions savings seen in this analysis.
- **Single-use plastic** bans can reduce the amount of difficult-to-recycle materials in the waste stream that would otherwise end up in landfills, saving the city money and greenhouse gas emissions.

@Lana Eslânia/MNCR

Written by: John Ribeiro-Broomhead. This case study was prepared as part of the report, "Zero Waste to Zero Emissions: How Reducing Waste Is a Climate Gamechanger (GAIA, 2022)." Please visit www.no-burn.org/zerowaste-zero-emissions to access the full report and detailed notes on data and methods.

eThekwini (Durban), South Africa

GHG reduction potential in Road-to-ZW scenario: 63%

@Graeme Williams

Key statistics (2017)

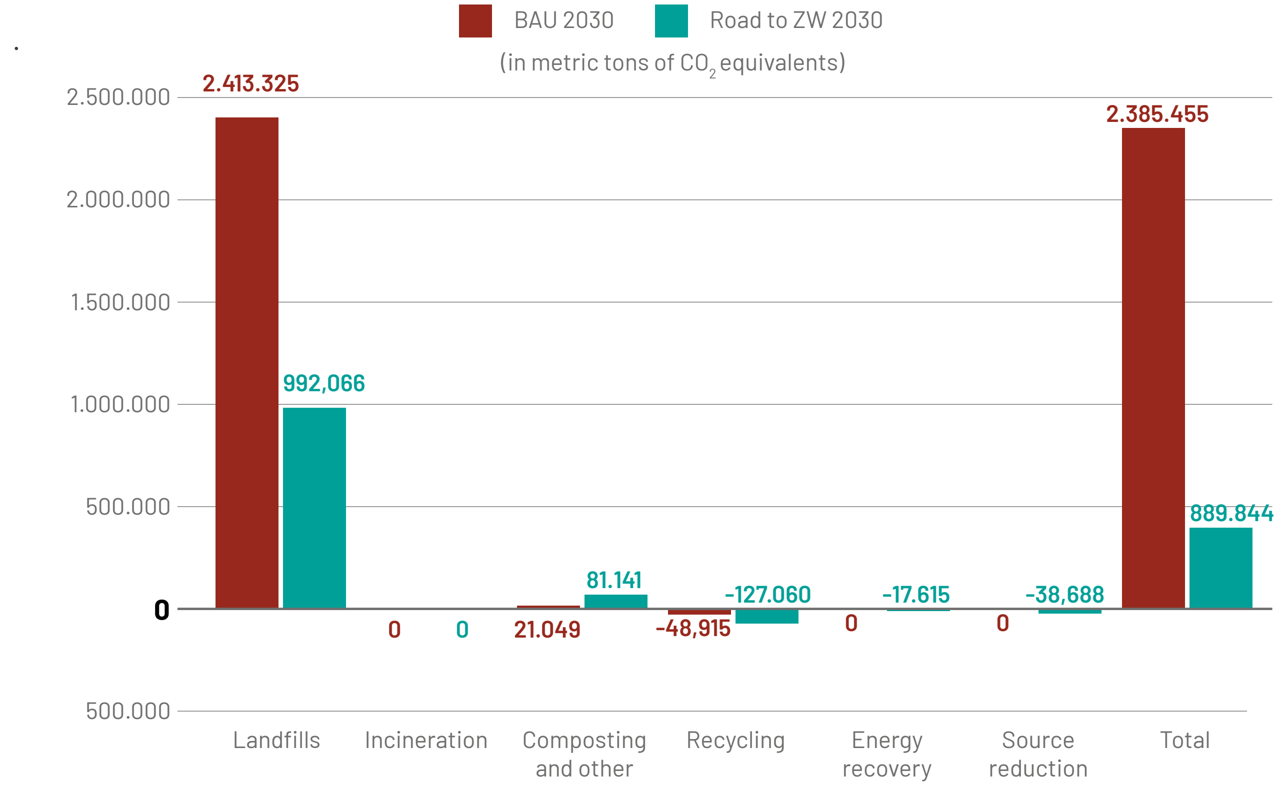
- **Population: 3,947,020**
- **Total municipal solid waste generation: 1,368,480 tonnes per year**
- **Per capita waste generation: 0.95 kg/day**
- **Waste collection system:**
  - <90% collection rate
  - Minimal separate collection by the municipality
- **Waste diversion rate: 10%**

The eThekwini municipality (Durban) is home to a patchwork of rural, peri-urban, and dense city neighborhoods with a range of economic resources. As many as 12% of households – largely in rural and informal housing settlements– do not receive official waste services. With negligible official separate collection and a discontinued curbside separate collection pilot program for household recyclables, the municipality relies heavily on waste pickers for material recovery. Conservative estimates of combined official and unofficial recovery rates suggest an overall material recovery rate of 10%, with unseparated waste being sent to landfill. But unofficial observations from experts in the area suggest much higher recovery rates for recyclables like PET bottles, paper, and cardboard through the informal sector. Despite this, the National Waste Picker Integration guidelines (2020) published by the Department of Forestry, Fisheries, and the Environment has yet to be implemented by the municipality, and informal waste workers still go unrecognized and unsupported. According to the 2016 Integrated Solid Waste Management plan, the municipality had set a goal of increasing the amount of recovered recyclables by 10% each year, but there are no official programs in place to achieve that goal.

Organic waste management presents a significant opportunity for the municipality to reduce the load on its increasingly expensive landfills, with food and garden waste making up 43% of the combined domestic and commercial waste stream. Integration and support for waste pickers allows for better tracking and execution of material recovery, particularly for easier-to-recycle materials such as paper and cardboard. This coupled with separate collection of food and garden waste could reduce its waste sector greenhouse gas emissions by as much as 63% (or 1,495,611 tonnes of CO_2e) relative to business as usual, the equivalent of preventing 750,000 tonnes of coal from being burned. Plans in the city's recently published Climate Action Plan to reduce the amount of good quality leftover food waste by 80% would generate additional GHG emissions savings.

eThekwini in 2030 – Business as Usual vs. Road to Zero Waste

The below chart shows estimates for annual GHG emissions associated with waste management in eThekwini by 2030 in two scenarios: 1) Business as Usual (BAU) based on the data from 2020, and 2) Road to Zero Waste based on consultations with local partners including the Urban Futures Centre of Durban University of Technology, groundWork, and Asiye eTafuleni. Assumptions that informed each scenario are detailed in the table below.



Treatment	BAU 2030	Road-to-ZW 2030
Landfill	1,335,017 tonnes of municipal solid waste landfilled per year Responsible for the entirety of GHG emissions	740,848 tonnes of municipal solid waste landfilled per year 45% reduction in landfilling, 59% reduction in landfill gas emissions
Incineration	none	none
Composting & other treatments	97,283 tonnes composted	333,041 tonnes composted
Recycling	79,555 tonnes officially; the informal sector handles much more	268,142 tonnes by strengthening the informal sector. Results in 2.6 times the GHG savings of BAU
Energy recovery	none	199,824 tonnes anaerobically digested, producing 17,615 tonnes CO_2e in emissions savings through energy generation
Source reduction	none	SUP restrictions avoid 44,997 tonnes of plastic and 38,688 tonnes CO_2e GHG emissions
Overall diversion rate	11%	47%

GHG reduction potential in Road-to-ZW scenario: 63%

Key takeaways

1 High organic content in eThekwini's waste stream makes separate collection and composting/anaerobic digestion critical to reducing the city's waste emissions, particularly from landfills. The food waste reduction goal in the city's Climate Action Plan is a step in the right direction, but there is a lot more that can be done to prevent organic waste.

2 In the Road to Zero Waste scenario, **eThekwini would achieve an increase in its overall diversion rate from 11% to 47%, avoiding annual GHG emissions by 1,495,611 CO_2e in 2030.**

3 **This approach would reduce annual residual waste by 46%, landfill methane emissions by 59%, and overall GHG emissions by 63%, compared to the Business as Usual 2030 scenario.**

4 The Road to Zero Waste scenario includes diverting 80% of organics from landfill to anaerobic digestion (37.5%) and composting (62.5%), increasing recycling rates to 80% for paper and cardboard recycling, doubling the amount of glass and metals recovered, and introducing a ban on single-use plastic.

5 Informal recyclers play a critical role in recycling in Durban, and the city has yet to recognize and support their grassroots efforts. Waste pickers' associations and environmental justice NGOs continue to advocate for the municipality to become an ally and partner in their efforts toward a zero waste city.

Recommendations

- **Organics**, which constitute 43% of the waste stream and are responsible for a large proportion of the municipality's baseline greenhouse gas emissions, should be separately collected and diverted from landfill to composting and/or anaerobic digestion, either at community-scale sites such as garden compost piles, or larger facilities depending on local community needs and resources. Fulfilling the goal set forth in the municipality's Climate Action Plan to reduce good quality leftover food in the waste stream by 80% is also critical to managing waste-related emissions.
- **Recyclables** should be managed through improved integration of the existing informal recycling system that already recovers significant amounts of paper, cardboard, and plastic that never enter the waste stream and are not captured by current data. The municipality should draw on the expertise of waste pickers to manage the most appropriate material recovery strategies for each neighborhood, including buy-back centers, door-to-door collection, and material recovery facilities.
- **Single-use plastic** should be banned in order to reduce the amount of difficult-to-recycle materials in the waste stream that can only go to landfill.

@Urban Futures Centre

gaia

Written by: John Ribeiro-Broomhead. This case study was prepared as part of the report, "Zero Waste to Zero Emissions: How Reducing Waste Is a Climate Gamechanger (GAIA, 2022)." Please visit www.no-burn.org/zerowaste-zero-emissions to access the full report and detailed notes on data and methods.

Seoul, South Korea

GHG reduction potential in Road-to-ZW scenario: 885%

@Yoohwa Jeong

Key statistics (2017)

- **Population: 9,639,541**
- **Total municipal solid waste generation: 3,594,301 tonnes/year**
- **Per capita waste generation: 1.02 kg/day**
- **Waste collection: 66% separation collection**
- **Waste diversion rate: 59%**

The city of Seoul — a home to near 10 million inhabitants — is the cultural, economic, business and political center of South Korea, and an epicenter of massive waste generation and carbon emissions, ranked as the world's thirteenth largest greenhouse gas emitter among cities globally. Since the 1970's, the city has witnessed rapid industrialization and expansion in all directions, including mass production and consumption and a throw-away lifestyle, which resulted in increased waste generation.

According to our GHG emissions analysis, however, Seoul's waste system is already a net-negative GHG producer thanks to robust separate collection and recycling system. The nation-wide application of the volume-based disposal system has been the key to recovering over 95% of food waste, 88% of metals, and 79% of glass. Only paper and cardboard (55%) and wood (56%) have relatively low recycling rates.

With little organic material going to landfills, methane from food waste is not a major concern; the majority of Seoul's GHG emissions come from its incinerators. Seoul currently operates four incinerators to process maximum 2,850 tonnes of waste each day, emitting 681,134 tonnes of CO_2e. With a direct landfill ban coming into effect in 2026, the government is looking to build more incinerators in the greater Seoul area, much like the incinerator build-out plan that the city had in 1991. Due to strong opposition expected from nearby communities, only four incinerators were built in the 1990's which ended up sourcing waste from other districts after struggling with a low processing rate.

In 2030, Seoul is projected to have a population of 9.16 million and per capita waste generation of 1.11 kg/day. As it's highly unlikely to find a place for landfills or incinerators in this densely-populated city, Seoul is left with one viable solution: zero waste centered around source reduction. The city already developed a roadmap toward a plastic-free future by 2022 (in 2018) as well as a carbon neutrality goal for 2050 (in 2020), with key policy elements included such as source reduction of waste, bans on single-use plastic, and expansions of reuse infrastructure. When these efforts are met with an incineration phase-out, the city can unlock the potential of saving over 885% of annual GHG emissions (or 538,220 tonnes of CO_2) by 2030, which is equivalent to annual emissions from 1.4 natural gas-fired power plants.

Seoul in 2030 – Business as Usual vs. Road to Zero Waste

The below chart shows estimates for annual GHG emissions associated with waste management in Seoul by 2030 in two scenarios: 1) Business as Usual (BAU) based on the data from 2019, and 2) Road to Zero Waste. Assumptions that informed each scenario are detailed in the table below.

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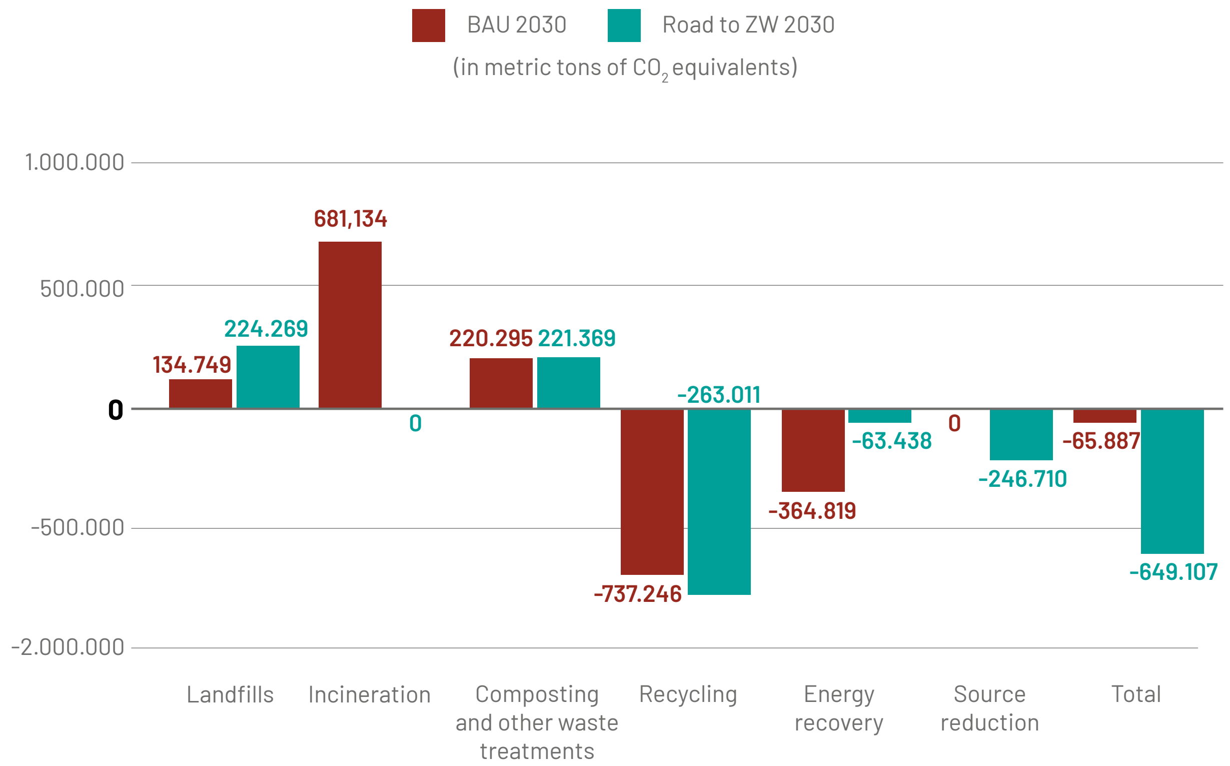


Treatment	BAU 2030	Road-to-ZW 2030
Landfill	378,173 tonnes of municipal solid waste landfilled per year Very little landfilling but still 13% of GHG emissions	1,057,795 tonnes of municipal solid waste landfilled per year. More landfilling but GHG emissions from landfill only go up by 89,520 tonnes CO_2e
Incineration	867,060 tonnes per year This produces 66% of Seoul's GHG emissions from waste	No incineration removes the largest source of GHG emissions: 681,134 tonnes
Composting & other treatments	96% of organics are composted or fed to animals	96% of organics are composted or fed to animals
Recycling	High recycling rates give Seoul a slightly negative carbon footprint	Strengthened recycling of paper and cardboard generate further emissions reductions
Energy recovery	The energy generated by incineration has twice the GHG emissions of replacement energy from the grid. Landfill gas energy is minimal because of low organics landfilling	Minimal energy recovery via landfill gas
Source reduction	none	Bans on single use plastic reduce plastic waste generation by 188,871 tonnes
Overall diversion rate	59%	64%

GHG reduction potential in Road-to-ZW scenario: 885%

Key takeaways

1 Seoul's waste system is already net-negative, with a 100% collection rate and a 96% organic waste diversion rate. With little organic material going to landfills, methane from food waste is not a major concern; the majority of Seoul's GHG emissions come from its incinerators.

2 In the Road to Zero Waste scenario**, Seoul would achieve an increase in overall diversion rate from 59% to 64%, avoiding annual GHG emissions by 583,220 tonnes CO_2e in 2030.**

3 **This approach would reduce annual residual waste by 15%, landfill methane emissions by 66%, and overall GHG emissions by 885%, compared to the Business as Usual 2030 scenario.**

4 The Road to Zero Waste scenario includes phasing out incineration, expanding bans on plastic bags, foam plastic, and other plastic packaging, and increasing recycling rate (80%) for paper, cardboard, and wood; all other recycling rates stay constant.

5 Civil society, including Korea Zero Waste Movement Network has played a vital role in tackling climate change with zero waste solutions, leading with a wide range of initiatives like SUP bans, building a reuse and refill culture, organizing for zero waste towns, and community outreach and education on waste prevention, sustainable production and consumption, and climate change.

@Korea Zero Waste Movement Network

Recommendations

- **Phase out waste incineration**. The city government's recent plan to build more incinerators by 2026 contradicts the nation's carbon neutrality goal for 2050. Shutting down the four existing incinerators alone would result in avoiding 681,134 tonnes annual CO_2e emissions in 2030. The city must withdraw the plan to build more incinerators by 2025 and gradually shut down incinerators as they are reaching the end of their life span in coming years.
- **Ban single-use plastic**. Continue and expand bans on single use items such as bags, cups, bottles, to-go containers, cutlery, etc.
- **Establish public-private governance** for greater public support on zero waste policies, and institutionally support the role of junk shops in collecting as much as 80% of discarded materials by amending the National Land Planning and Utilization Act.

gaia

Written by: Doun Moon. This case study was prepared as part of the report, "Zero Waste to Zero Emissions: How Reducing Waste Is a Climate Gamechanger (GAIA, 2022)." Please visit www.no-burn.org/zerowaste-zero-emissions to access the full report and detailed notes on data and methods.

@ Rahadiansyah

Bandung, Indonesia

GHG reduction potential in Road-to-ZW scenario: 50%

Key statistics (2017)

- **Population: 2,500,965**
- **Total municipal solid waste generation: 638,997 tonnes/year**
- **Per capita waste generation:0.70kg/day**
- **Recycling rate: 6.64%**

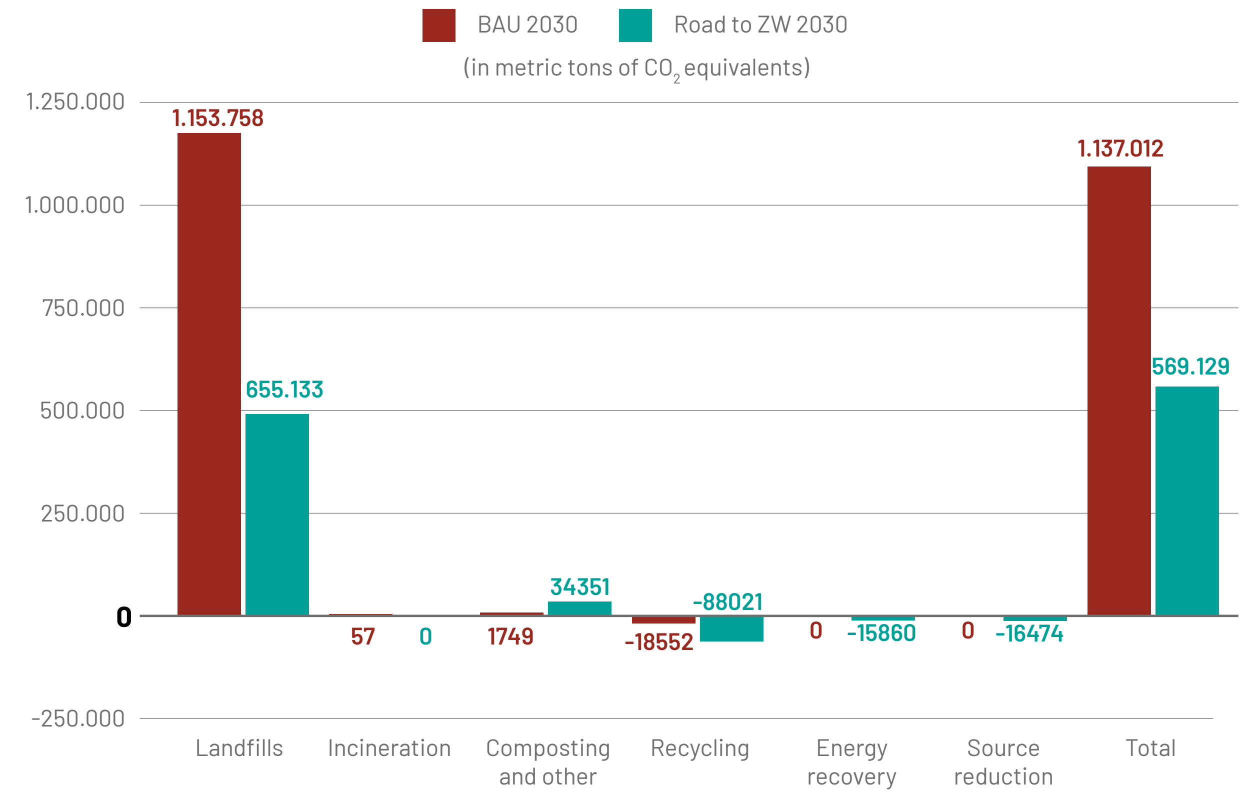
Bandung is the capital of West Java Province with a population of 2.5 million which is expected to reach 2.6 million by 2030. During daytime, Bandung receives an additional 1.2 million people from the surrounding regencies/cities. According to YPBB Bandung's estimation, the waste generation rate in 2020 has reached 0.70 kg/capita/day and is projected to reach 0.78 kg/capita/day by 2030. Nearly half the waste stream is organic waste (44.51%) and plastic comes in the second (17%). There is only little recycling currently happening in Bandung — only about 6% of the waste is collected for recycling, primarily dominated by paper and cardboard (29,021.6 tonnes/year), followed by plastic (9,270.5 tonnes/year) then organic waste (4,111.1 tonnes/year). There are no official data that record the amount of waste informal sectors collected for recycling. The rest is sent to the landfill with no gas collection.

Along with waste generated by the neighbouring regencies/cities, Bandung disposes of its waste in the Sarimukti Landfill. Historically, Sarimukti Landfill started its operations after Leuwigajah Landfill (the previous regional landfill) collapsed in 2005 — resulted in the deaths of hundreds of people and caused Bandung to be filled with waste. After operating for 15 years, Sarimukti Landfill has reached its maximum capacity and caused several occasion when the waste hauling process to this landfill got distrubed. Given the situation, the government plan to move the regional landfill to a new location in Legok Nangka and instal waste-to-energy incineration technology. However, due to the high tipping fee that burdens the city, Bandung government has realized that the best way is reducing the waste transported to the landfill with various approaches through an existing Zero Waste Cities program (in local language: Kang Pisman).

Since its inception in 2017, Zero Waste Cities in Bandung has reached almost 12,000 households and 60,000 people in Bandung, and has been adopted as Kang Pisman program by Bandung City Government. The compost produced from organic waste processing in the area has also encouraged the development of urban farming and community gardens.

Bandung in 2030 — Business as Usual vs. Road to Zero Waste

The below chart shows estimates for annual GHG emissions associated with waste management in 2030 in two scenarios: 1) Business as Usual (BAU) and 2) Road to Zero Waste based on consultations with local groups including Yaksa Pelestari Bumi Berkelanjutan (YPBB). Assumptions that informed each scenario are detailed in the table below.



Treatment	**BAU 2030**	**Road-to-ZW 2030**
Landfill	692,774 tonnes of municipal solid waste landfilled	Only textiles, rubber and leather, diapers and hygienic products, and other waste are landfilled (403,271 tonnes/year, 42% in municipal solid waste landfilled)
Incineration	Minimal (open burning and some small-scale incinerators)	No burning of waste in waste-to-energy incinerator facilities and cement kilns
Composting & other treatments	Limited access to composting	105,721 tonnes (18.04% of total waste) composted — both food and garden waste
Recycling	Minimal recycling through waste bank initiatives and informal sector activities	Divert 16% of total waste by recycling (paper & cardboard, glass, and metal)
Energy recovery	Mixed waste and residual is converted into Refuse-derived Fuel (RDF) and sent to cement kilns. Minimal biodigestion	54% of food waste (93,377 tonnes) is treated with anaerobic digester
Source reduction	Limited source reduction program, only single-use plastic bag ban in retailer	Reduce 30% of total waste at source (44% through food waste prevention and 100% of plastic through SUP bans and reuse/refill
Overall diversion rate	7%	42%

Estimated GHG reduction from Road-to-ZW scenario: 50%

Key takeaways

1 The major source of GHG emissions in Bandung is methane emissions from landfilled organic waste.

2 **If the current status continues, annual emissions from landfills in Bandung will amount to 1,153,758 tonnes CO_2e by 2030.**

3 **In the Road to Zero Waste scenario, Bandung would achieve an increase in overall diversion rate from 7% to 42%, avoiding annual GHG emissions by 498,625 tonnes CO_2e in 2030. This is equivalent to over 5% of Indonesia's NDC unconditional target.**

4 The Road to Zero Waste scenario includes diverting 81% of waste from being landfilled and incinerated by 2030. More than half of that diversion percentage comes from food waste prevention and organic waste treatment program (49%). An aggressive single-use plastic ban program coupled with reuse/refill program would also result in 17% diversion rate. The rest comes from glass, metal, paper and cardboard recycling.

5 This approach would reduce annual residual waste by 42%, landfill methane emissions by 43%, and overall GHG emissions by 50%, compared to the BAU 2030 scenario.

Recommendations

Both local and central government should **ensure 100% separated waste collection, maximize waste treatment, and focus on waste prevention** with a focus on **food loss prevention, single-use plastic ban, and refill/reuse systems.** As for waste treatment, 100% organic waste should be treated through decentralized composting and anaerobic digestion. Lastly, separated waste collection will maximize recycling for paper and cardboard, glass, and metal.

This can be done through national policy reforms by the central government which can be achieved in a relatively short time with the right political will to issue these required enabling policies:

- Create sufficient institutional capacity through the inclusion of environment sector as part of the government's basic service. It will enable local governments to allocate sufficient budget and execute low-tech and labour intensive waste prevention and reduction programs.
- Strengthen local government capacity through distribution of roles and responsibilities.
- Currently, the role of financing and operating waste management service is put solely on the local government, specifically the Environment Agencies. Once these roles are spread among institutions at various levels, the local government's burden on waste management will decrease.
- Allow local governments to expand law enforcement capacity for faster implementation of the single-use plastic ban as part of achieving a national target
- Stop ongoing and planned thermal waste treatment projects (i.e. waste-to-energy incineration, RDF burning in cement kilns, coal-fired power plants, or other industrial plants). These projects will lock cities in carbon-intensive waste infrastructure and undermine waste prevention and separation collection, wasting limited public funds on stranded assets.

@YPBB

Written by: Yobel Novian Putra. This case study was prepared as part of the report, "Zero Waste to Zero Emissions: How Reducing Waste Is a Climate Gamechanger (GAIA, 2022)." Please visit www.no-burn.org/zerowaste-zero-emissions to access the full report and detailed notes on data and methods.

Detroit, USA

GHG reduction potential in Road-to-ZW scenario: 102%

@Wigwam Jones

Key statistics (2017)

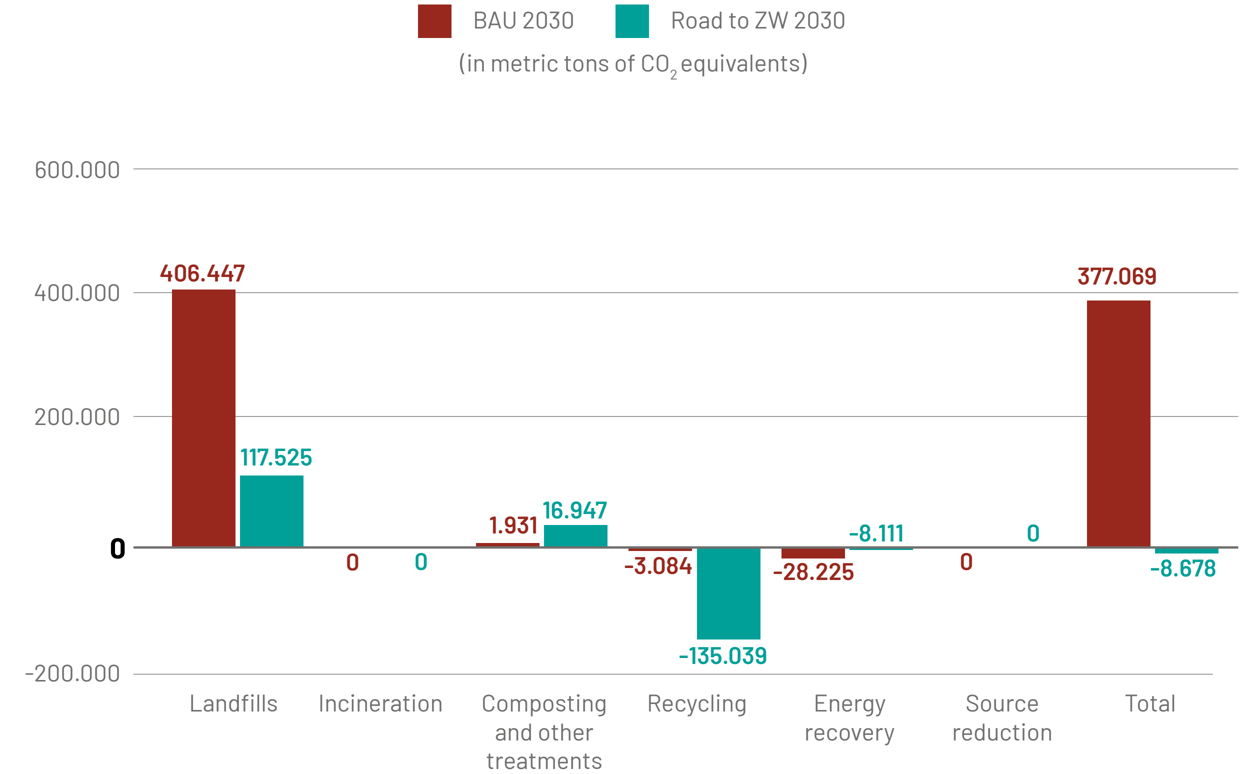
- **Population in 2021: 632,464**
- **Total municipal solid waste generation: 493,188 tonnes of waste per year (including residential and commercial, illegal dumping, bulky waste streams)**
- **City declared diversion rate: 4.15%**
- **Curbside recycling participation rate (2022): 38%**

Once the wealthiest city in the United States on a per capita income basis, Detroit has undergone decades of socioeconomic downturn and remains the second poorest large city in the country and the most segregated. Despite the fact that Detroit is undoubtedly experiencing gradual economic resurgence, the city has been struggling with de-industrialization, divestment, and a declining population. Until recently, the city was host to one of the largest municipal waste incinerators in the U.S., which burned not only the city's waste, but that of surrounding suburbs and even Canada, at a substantial financial loss, and with severe impacts on residents' health. The overcapacity of the incinerator discouraged investment in alternative approaches to waste management, resulting in very low rates of recycling, composting, or other forms of waste diversion. After decades of grassroots advocacy efforts and campaigns, such as the ultimately successful Breathe Free Detroit campaign, spearheaded by the Zero Waste Detroit (ZWD) Coalition in collaboration with some of its key member organizations, the East Michigan Environmental Action Council, the Great Lakes Environmental Law Center, and the Ecology Center, residents finally succeeded in closing down the incinerator in 2019, and are now grappling with the task of transitioning the city's existing waste management system into a sustainable materials management one. Confronted with systemic injustice, Detroiters have come to be on the leading edge of grassroots community activism and organizing efforts, as well as artistic and cultural creation, to make their city a more sustainable, equitable, and just place to live.

Detroit was the last major metropolitan area in the U.S. to implement a citywide curbside recycling program in 2014, which partially explains the current low waste diversion rate of 4%, far under the State's 19.3% rate. However, the official diversion rate doesn't reflect efforts led by Detroit-based grassroots community organizations, urban farms, food rescue programs, a university, and local recycling, upcycling, and composting companies. In 2021, these grassroots networks have diverted at least 2,3336 metric tons of material, which have not been included in the 19,955 metric tons of materials that the city declared as being diverted that same year. That being said, a significant portion of Detroit's waste diversion and zero waste initiatives of the past 10+ years have been led and/or initiated by the city's grassroots networks. Their initiatives include: implementing a community recycling drop-off center funded by the city; increasing the city's opt-in single-stream curbside recycling program participation rate through community education and outreach campaigns; managing food rescue programs; building citywide decentralized compost networks; running robust informal upcycling, sharing, reuse, donation and repair networks; and forming committees to advise Detroit City Council on sustainability principles and policies. Currently, collaborative efforts among grassroots activists and the city are taking place to bring a material recovery facility (MRF) to Detroit, as well as to develop a city-lead opt-out curbside recycling pilot program, and a citywide composting system, amongst others.

Detroit in 2030 – Business as Usual vs. Road to Zero Waste

The below chart shows annual GHG emissions estimated for Detroit by 2030 in two scenarios: 1) Business as Usual based on the data from 2021 collected from the City of Detroit's Department of Public Works (DPW), Resource Recycling Systems (RRS), NextCycle Michigan, and 2) Road to Zero Waste based on consultations with DPW, RRS, and 22+ community partners, including local recycling and composting companies, grassroots organizations, urban farms, businesses, and policymakers. Assumptions that informed each scenario are detailed in the table below.



Treatment	BAU 2030	Road-to-ZW 2030
Landfill	437,466 tonnes of municipal solid waste landfilled – The source of virtually all emissions	740,848 tonnes of municipal solid waste landfilled per year 45% reduction in landfilling, 59% reduction in landfill gas emissions
Incineration	none	none
Composting & other treatments	10,397 tonnes	80,338 tonnes
Recycling	5,731 tonnes through voluntary drop-offs and curbside recycling	208,405 tonnes through an increase in the city's curbside recycling program. The emissions reductions of recycling alone are greater than the emissions from landfilling.
Energy recovery	-28,225 tonnes CO_2e from landfill gas to energy	-8,111 tonnes CO_2e from landfill gas to energy
Source reduction	none	none
Overall diversion rate	4%	59%

GHG reduction potential in Road-to-ZW scenario: 105%

Key takeaways

1 The major source of GHG emissions in Detroit is methane emissions from landfilled organic waste, which will amount to 406,447 metric tons of CO_2e by 2030 in the Business As Usual scenario.

2 In the Road to Zero Waste scenario, **Detroit would achieve an increase in overall diversion rate from 4% to 59%, avoiding annual GHG emissions by 385,747 tonnes CO_2e in 2030. This is equivalent to emissions from 48,590 homes' energy use for one year.**

3 **This approach would reduce annual residual waste by 62%, landfill methane emissions by 71%, and overall GHG emissions by 102%, compared to the BAU 2030 scenario,** transforming Detroit's waste sector from being a major emitter of GHGs (377,069 metric tons of CO_2e by 2030) to a net-negative sector (-8,678 metric tons of CO_2e by 2030).

4 The Road to Zero Waste scenario includes 80% diversion of organics, glass, metals, wood, paper and cardboard, and 15% diversion for plastic and textiles, with electronic waste and other recycling remaining approximately constant (overall 59% diversion).

5 Generational inequities and injustices need to be addressed in order for a more zero waste, climate resilient, and equitable Detroit to be truly possible. Supporting the powerful grassroots work already taking place in Detroit is the key to strengthening meaningful zero waste and sustainability solutions.

Recommendations & vision for 2030

- **Increased City leadership and engagement to promote zero waste** through more effective data tracking of Detroit's MSW streams; performing a cost-benefit analysis for increasing waste diversion services; mass promoting those services to residents through messaging platforms (buses, signage, ads) ; investing in existing and much needed new waste diversion infrastructure; building staff capacity for sustainability
- **Overcoming state and local policy roadblocks for zero waste by**, 1) Amending Michigan's Waste Solid Disposal Law with Part 115, an 8 bill package proposing to transition Michigan to a sustainable materials management paradigm; 2) Amending Detroit's Solid Waste & Illegal Dumping Ordinance into a Sustainable Materials Management one; 3) Increasing landfill tipping fees to incentivize waste reduction, composting and recycling; 4) Removing the renewable energy credits being provided by the State to waste-to-energy facilities; 5) Implementing an equitable Extended Producer Responsibility law in Michigan; 6) Repealing the ban on the ban (also known as Preemption Law) on single-use plastic (SUP) bags so municipalities like Detroit can regulate SUPs; 7) Developing union-led workforce development opportunities in the field
- **Increasing public awareness through education and outreach** to youth in public schools and residents and businesses (citywide litter prevention, waste diversion and reduction, citizen science campaigns and trainings)
- **Increasing Detroit's recycling diversion rate** by making recycling services available to all by 2030; reducing contamination through further resident education and glass recycling improvements; building up Detroit's MRF and drop-off center capacity
- **Implementing a citywide integrated network of multiscale (household, community, industry) compost systems** by increasing the city's organics management infrastructure; supporting urban farmers in their collection efforts; increasing public outreach and education efforts; creating onsite organics managements projects for large scale entities; and recirculating city-made compost within city borders
- **Increasing food rescue capacity for the city**, by having centralized food donation infrastructure like in Milan; further training the public and businesses about food waste prevention and reduction; and implementing a citywide food waste ban
- **Localizing our supply chains and building micro circular economies** with nonprofit trading posts for teaching materials and other giveaways, fix-it and reuse centers, a reusable to-go containers program for restaurants, and hyperlocal labor and materials processing and end-markets, as well as delivery systems for locally grown food and secondhand goods.
- **Utilizing matching funds from the State's NextCycle Michigan program**, which can provide financial assistance to meet many of these goals. The City of Detroit has applied for funding with NextCycle and there are significant plans and ideas to implement many of the above recommendations.

@Garrett MacLean

gaia

Written by: Cat Diggs. This case study was prepared as part of the report, "Zero Waste to Zero Emissions: How Reducing Waste is a Climate Gamechanger (GAIA, 2022)." Please visit www.no-burn.org/zerowaste-zero-emissions to access the full report and detailed notes on data and methods.

5.3. **Lessons Learned**

Several commonalities emerge from the GHG analyses of eight cities. First, zero waste policies and programs, even incompletely implemented, confer major mitigation benefits everywhere. Emissions reductions ranged from 50% to 105% against a business-as-usual scenario. These deep cuts were achieved with relatively modest system changes, as described above. Complete implementation of the zero waste model would deliver even deeper emissions cuts.

The key to deep emissions reductions is source separated collection and treatment of organic waste. In all cities but Seoul, which already separately collects 96% of its organic waste, landfill methane is the primary source of GHG emissions in the waste system. Separate collection and treatment of organics – usually through composting – reduces these emissions by 43% to 83%, even with incomplete implementation. This approach is the only effective method to fully address these emissions.

Burning waste, whether with energy recovery or not, results in massive GHG emissions. In Dar Es Salaam, the only city in this study with wide-scale open burning, ending the practice would reduce GHG emissions almost half as much as ending landfill methane emissions (in addition to significant public health benefits). In Seoul, scenarios that continue to rely on incineration fail to achieve deep emissions reductions, because incineration is itself a major source of GHG emissions.

While organics are essential to emissions reductions, recycling creates the possibility of a net-negative waste sector. Increased recycling reduced emissions between 3% and 35%. In Sao Paulo and Detroit, this is sufficient to make the waste sector net negative – reducing more emissions than it produces. Recycling reduces emissions in the industrial, agricultural, forestry, and energy sectors as well as emissions from waste management. Source separation can strengthen recycling rates by reducing cross-contamination (for example, mingling food waste with paper renders the paper valueless). Current recycling rates are lower than technically possible because of a lack of financial incentives to recycle. These financial challenges affect both city-run recycling programs and the informal sector, which is the backbone of recycling in many countries. Strengthening and incorporating the informal sector can yield very high recycling rates. Although not captured in our analyses, rising levels of plastic use are a threat to high recycling rates: most plastic is not recyclable, and it tends to displace other, more recyclable materials.

Generating energy from waste is not an effective mitigation measure. Cities that rely on landfill gas capture (Detroit, São Paulo, and Temuco) and incineration (Seoul) see relatively small GHG savings from displacing fossil energy sources while allowing large quantities of methane (from landfills) and fossil CO_2 (from incinerators) to escape to the atmosphere. Landfill gas collection is plagued by low capture rates and break downs. As the electric grid decarbonizes, the benefits of waste-derived energy will continue to shrink.

Seoul is a unique but instructive case: it is the only city in our study that currently has a net negative waste sector, due to its successful organics diversion program and overall high recycling rate. However, its program is marred by its reliance on incineration, which produces twice as much as GHGs as replacement sources of energy. Ending incineration and improving recycling in Seoul would increase its GHG savings by an order of magnitude. Replacing existing incinerators with renewable energy would further deepen these cuts. Seoul also stands to benefit the most from source reduction of plastic, both because of its high current plastic use rate and because its plastic reduction program is more ambitious than other cities'.

Another common theme is the underutilization of source reduction strategies. Upstream reductions, particularly of food and plastic, can trigger significant GHG emissions reductions throughout the supply chain, as well as in the waste sector. These programs, such as bans on plastic bags and plastic take-out containers, are largely in their infancy and should be dramatically expanded.

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6. Conclusions and recommendations

With its potential to dramatically reduce short-term methane emissions, and even function as a "net-negative" sector, waste management can and should play an instrumental role in climate action. Zero waste systems deliver mitigation, adaptation, and additional benefits by source reduction for both organics and non-organic waste, and following the waste hierarchy as subsequent lines of action. For cities, zero waste is an opportunity to take a leadership role in climate action.

As this report has outlined,

> *zero waste systems not only benefit society through climate mitigation and adaptation, they also enhance community health, environmental justice, and local economic development.*

Investments in waste reduction, separate collection, and material recovery increase environmental resilience, and can improve the broader economic state by creating green jobs and new business opportunities.[251]

Previous analyses and the experience of hundreds of cities around the world show that zero waste is a practical, rapid, and affordable waste management strategy. Many cities have already achieved diversion rates above 50% within a few years of beginning implementation. Zero waste is far more economical than capital-intensive alternatives such as incineration and engineered landfills; it also generates significant economic benefits in terms of new and better jobs and new business opportunities.

While the principles of zero waste remain the same everywhere, the manner of implementation is specific to each cities' economic and environmental context. With a large focus on community engagement, the implementation of zero waste systems has consistently proven to reduce overall waste generation and waste disposal rates, and to boost compliance in source separation in short periods of time. Examples all around the globe.

A resilient city is able to respond quickly and effectively to climate change, in an equitable and efficient way. When implementing zero waste systems to better withstand the impacts of climate change, considerations for marginalized groups are critical, as climate change will place unique and accentuated burdens on them. These include residents of low-income communities and informal settlements, especially women, children, the elderly and disabled, and minority populations. The work of building resilience must therefore be based upon a strong web of institutional and social relationships that can provide a safety net for vulnerable populations.

In the light of the above, this reports puts forward the following recommendations:

- **Incorporate zero waste goals and policies into climate mitigation and adaptation plans.**
  - Cities, which have the primary responsibility for waste management, should adopt comprehensive zero waste programs, with emphasis on source separation, organics treatment, and informal sector integration.
  - Funders and financial institutions should support city transitions to zero waste with financial and technical measures.
  - National governments can incorporate zero waste into their Nationally Determined Contributions (NDCs) and relevant national climate policies.
- **Prioritize food waste prevention and single-use plastic bans.**
  - Food waste prevention requires a dedicated strategy that integrates the entire supply chain, with interventions from field to fork.
  - Bans on single-use products and packaging, particularly plastic, can be adopted at the local or national level.
- **Institute separate collection and treatment of organic waste.**
  - Cities should develop clear, easy-to-use systems with uniform signage and dedicated outreach programs to ensure high compliance rates.
  - Composting is the easiest, least expensive, and most scalable treatment option for organic waste.
- **Invest in the waste management systems, recycling and composting capacity.**
  - Relatively small capital inputs are required for source separated collection, material recovery facilities, organics treatment, etc.
  - Municipalities should create a plan to meet ongoing operational costs, which may be lower under zero waste.
- **Establish appropriate institutional frameworks for zero waste including regulations, educational and outreach programs, and provide financial incentives through subsidies to recycling and composting.**
  - Regulations to set up a comprehensive zero waste system are key, with strong emphasis on aligned economic incentives that promote a virtuous system, continuously improving its waste reduction rates.
  - Subsidies and other incentives to compost production and use are instrumental in developing these virtuous systems that can counter the heavily subsidized synthetic agrochemicals.
  - Education, communication and outreach programs which ensure all stakeholders are included are needed for high participation and compliance rates.
- **Recognize the role of waste pickers and fully integrate them into the waste management system.**
  - Create a consultative mechanism through which waste pickers can actively collaborate in the design of zero waste and take advantage of new opportunities, whether as employees or as entrepreneurs.
  - In cities where informal recyclers come from historically excluded populations, this may require ending long-standing discriminatory practices.

More information on zero waste implementation, including best practices for source separation, how to finance zero waste, and step-by-step guides, is available on the GAIA website at www.no-burn.org/zw-guides.

The urgency of climate action is greater than ever before. The scientific community has made clear that we are not doing enough to limit global warming to the crucial 1.5°C threshold. Yet we have solutions in our hands. As this report shows, we have come a long way in our ability to identify what works best for people and the planet. The challenge now is to gather the political will to implement these solutions quickly and at scale, while ensuring that all stakeholders are included and that justice is not sacrificed along the way.

Zero waste strategies show a way forward and give us reasons to be hopeful. By starting with small steps toward separate collection of waste, and further building up zero waste systems to maximize source reduction and material recovery, cities can ameliorate the catastrophes of climate change, while reaping additional benefits in all directions. With zero waste, cities can take concrete actions toward climate mitigation and resilience in the waste sector, raising the ambition of national pledges made under the Paris Agreement and closing the emissions gap.

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6. Appendix: data and methodology

Please visit www.no-burn.org/zwze-data-and-methodology for detailed notes on data sources and methodology of the analysis.

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