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Zero Waste as An Effective Climate Strategy: Avoiding Warming Tradeoffs from Incineration

Executive Summary

As global temperatures continue to rise, cutting methane emissions has become an urgent global priority. Methane traps over 80 times more heat than carbon dioxide (CO_2) over a 20-year period and is responsible for roughly a quarter of current global warming.[1,2] The waste sector, particularly the uncontrolled decomposition of organic waste in landfills and dumps, is a major contributor to global methane emissions. In response, **cities and countries are increasingly pursuing waste sector reforms as part of their climate strategies**.

This report assesses the long-term global warming impacts of three waste management strategies — business-as-usual disposal-based practices such as dumping and landfilling (BAU), incineration, and zero waste practices such as source separation and treatment of organics and recyclables (ZW). The analysis focuses on three urban contexts: Lagos (Nigeria), Barueri (Brazil), and Quezon City (Philippines). Using the Solid Waste Emissions Estimation Tool (SWEET) and the Finite Amplitude Impulse Response (FaIR) climate model, the analysis calculates projected temperature impacts for each strategy through 2060.

By modeling actual warming outcomes rather than relying solely on emission metrics like carbon dioxide-equivalent (CO_2e), this approach avoids common accounting distortions. These metrics compress the different lifetimes and warming impacts of gases such as short-lived methane and long-lived CO_2 into a single value, obscuring near-term climate effects. **By directly modeling temperature outcomes, this analysis provides a clearer, more policy-relevant picture of how different waste interventions actually shape climate trajectories over time.**

Key Findings

- ZW consistently outperforms incineration and BAU in all three cities, delivering the greatest reductions in long-term warming. In Quezon City and Lagos, ZW results in up to nine times more avoided warming than incineration by 2060, preventing warming equivalent to removing over 11 million and 100 million cars from the road for a year in Quezon City and Lagos, respectively. In Barueri, where the incineration scenario assumes an unusually favorable case of burning 100% of the city's waste — far more than typical municipal incinerators — ZW still performs nearly 40% better, preventing warming equivalent to that caused by over 650,000 cars driving for a year.
- Incineration provides modest to negligible climate benefits, mostly from short-term reductions in methane. These gains are ultimately outweighed by long-lived CO_2 emissions from burning organic and recyclable materials.
- To achieve comprehensive levels of incineration, Quezon City would need to build an additional three incinerators, while Lagos would need to build an additional seven — equivalent to 4 and 8 times their current planned incineration capacities, respectively. Given the high cost, political resistance, and long timelines associated with building even a single facility, such expansion is not only unrealistic, but also far less effective than scaling up zero waste strategies.
- ZW strategies minimize both methane and CO_2 emissions through source separation, composting, recycling, and reduced reliance on landfilling or combustion. These benefits compound over time, especially as CO_2 becomes the dominant driver of warming in the medium to long term. Adding upstream waste prevention, repair, and reuse strategies, which were not included in this analysis, would further improve the ZW scenario's performance.
- The performance gap between ZW and incineration grows over time. As cities grow and waste volumes increase, the long-term climate benefits of zero waste become more significant.

This analysis confirms that zero waste offers the most effective and climate-aligned pathway for addressing emissions from the waste sector. By reducing both methane and CO_2, it supports international climate commitments such as the Global Methane Pledge, the Paris Agreement, and the Declaration on Reducing Methane from Organic Waste. Incineration, by contrast, offers only short-term methane reductions while driving long-term warming through persistent CO_2 emissions.

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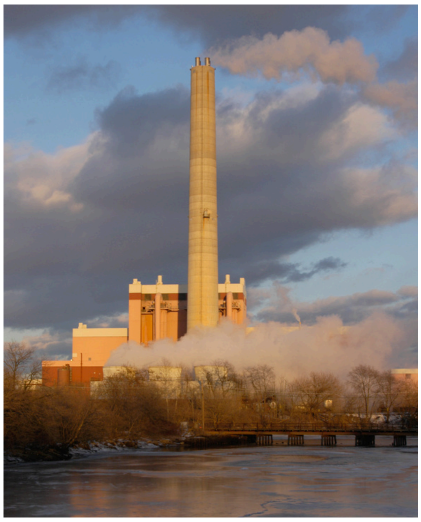
Introduction

As the climate crisis intensifies, methane reduction has emerged as a critical global priority for near-term climate mitigation. Methane is a potent greenhouse gas, over 80 times more powerful than carbon dioxide over a 20-year timescale, and is responsible for roughly 20-30% of observed global warming to date.[1,2] In response, countries have committed to ambitious methane targets under frameworks such as the Global Methane Pledge, the Paris Agreement, and the Declaration on Reducing Methane from Organic Waste adopted at COP29. These efforts have collectively placed the waste sector, responsible for an estimated 20% of anthropogenic methane emissions,[3,4] under increasing scrutiny and political pressure.

Methane from the waste sector is primarily generated through decomposition of organic materials in oxygen-starved landfills and dumpsites (also known as anaerobic decomposition), many of which remain poorly managed or entirely uncontrolled. In rapidly urbanizing cities across the Global South, waste systems often rely on open dumping and household-level burning, with limited coverage by formal collection services. These conditions present both an environmental liability and a critical intervention opportunity. As a result, assessing the role of waste in national climate commitments is increasingly important, a need addressed in other publications such as GAIA's 2024 NDC Checklist.[5]

However, the approach taken to achieve methane reductions will determine whether these interventions deliver durable climate benefits or lock in long-term harm. Industry actors and some national governments have promoted waste incineration, often referred to as "waste-to-energy" (WTE), as a quick and technologically expedient solution to landfill-related emissions. These proposals have gained traction in some climate funding pipelines and national waste plans, particularly in cities struggling with mounting waste volumes and limited landfill capacity.

While incineration can reduce landfill methane emissions by diverting organic waste from landfills and dumps , it introduces significant carbon dioxide emissions — both biogenic and fossil carbon — that have a larger impact on global warming over the long-term.



These CO_2 emissions contribute to long-lived atmospheric warming, offsetting any near-term gains from methane reduction. Moreover, incinerators undermine waste prevention and recycling systems by requiring a steady, substantial stream of combustible waste. This disincentivizes organics diversion and the recovery of recyclables for the entire lifetime of the incinerator, locking out these superior solutions for decades to come. In cities where informal workers already perform high levels of recycling and composting without formal support, incineration additionally threatens to displace livelihoods and reduce overall system efficiency.[6]

This report evaluates the long-term warming impacts of three distinct waste management strategies — business as usual (BAU, which relies primarily on landfilling or dumping), incineration, and a zero waste (ZW) scenario that incorporates key interventions such as source separation and treatment of organics and recyclables — in three urban contexts: Lagos, Nigeria; Barueri, Brazil; and Quezon City, Philippines. While the ZW scenario includes core zero waste strategies like composting and recycling, it does not represent a comprehensive zero waste system; upstream approaches such as waste prevention, repair, and reuse were not included in the modeling. Each scenario was modeled using the Solid Waste Emissions Estimation Tool (SWEET) to estimate greenhouse gas emissions, which were then analyzed through a simple climate model called the Finite Amplitude Impulse Response (FaIR) model to assess projected warming impacts through 2060, a timeframe consistent with a standard lifetime of a landfill or incinerator facility.

Methodology Overview

Greenhouse gas emissions for each modeled scenario were estimated using the Solid Waste Emissions Estimation Tool (SWEET), a calculator developed by the US Environmental Protection Agency (EPA) to help cities understand how different waste management strategies affect emissions over time.[7] SWEET considers a range of treatment methods, including landfilling, composting, recycling, and incineration, and allows for customization based on local waste composition and infrastructure. SWEET is designed to capture the diverse reality of waste management practices around the world, including open dumping and burning. In SWEET, biogenic CO_2 emissions from incineration and open burning are included by default, whereas biogenic CO_2 from landfilling and composting is not included. To ensure consistency across pathways, biogenic CO_2 from landfilling and composting was calculated separately and added to this analysis using emission factors sourced from peer-reviewed literature.

Conditions for the three scenarios can be summarized as follows:

- BAU: Reflects existing practices, which vary by city and include different combinations of open dumping, landfilling (with or without landfill gas capture), open burning, limited recycling, and minimal organics management.
- Incineration: Reflects the waste volumes and facility capacities outlined in actual municipal incinerator proposals and permitting documents for each city. All available recyclables are assumed to be diverted to incineration to ensure that waste burns hot enough to maintain efficient and stable combustion.
- ZW: Utilizes source separation and management (composting/anaerobic digestion, recycling), with targets set at 80% separation and treatment of organics, and 40-60% capture of recyclables depending on local waste composition. Upstream waste reduction was not considered in this scenario due to limitations of the modeling tool. While these diversion rates do not reflect a full zero waste system, they represent achievable targets based on real-world examples (see methodology appendix).

The resulting emissions estimates were then used as inputs to the Finite Amplitude Impulse Response (FaIR) climate model, a tool used by researchers and policymakers to evaluate the global warming impacts of different types of greenhouse gas emissions.[8] The model was run from 2026 to 2060, reflecting the expected operational life of major waste infrastructure projects such as landfills or incinerators. The model was run using the same set of climate assumptions and levels of variability across all scenarios and cities. Absolute temperature results were then compared to one another to calculate the relative impact of the different scenarios. BAU is treated as the baseline (zero line on the results graphs), with the incineration and ZW results shown as deviations from that baseline. In reality, BAU would contribute to global warming over time, but this approach isolates the relative climate impact of adopting the different strategies.

Using FaIR in this way allows for assessment of the modeled waste management strategies in terms of actual warming impacts on global average temperature. While emissions inventories and CO_2e accounting can be useful, they do not directly reflect how different gases contribute to temperature change over time. Conversion metrics like Global Warming Potential (GWP) compress the warming effects of various greenhouse gases into a single value, but can obscure important differences in how gases behave in the atmosphere, particularly on shorter timescales. Methane, for instance, is far more potent than CO_2 in the short term, but CO_2 persists in the atmosphere for centuries. This makes it difficult to evaluate the real-world warming consequences of strategies that reduce one gas while increasing another. By modeling actual temperature response rather than relying on CO2e values, this approach offers a more accurate and policy-relevant analysis. Temperature results are presented in microdegrees °C (millionths of a degree Celsius) of warming or cooling relative to BAU, reflecting the global impact of local waste management strategies.

In all scenarios, waste generation was assumed to grow at a steady rate based on population trends, and no upstream waste reduction was included, though this would strengthen the benefits of the ZW approach even further in potential future analyses. Key assumptions about how much waste could be diverted or incinerated were based on local studies, municipal plans, academic literature, and expert consultation. For full details on data sources, scenario design, and technical model inputs, please see the methodological appendix.

Findings

The modeled temperature differences relative to the business as usual scenario reveal a clear pattern across all three cities: **the zero waste pathway consistently delivers the greatest reduction in warming**, outperforming BAU and incineration across the board.

Lagos, Nigeria

Population: ~21 million
Waste generation: ~0.6 kg/person/day
Primary disposal methods (BAU): Open dumping at Olusosun dumpsite and other informal sites; open burning; limited formal collection; informal recycling by waste pickers; minimal organics diversion

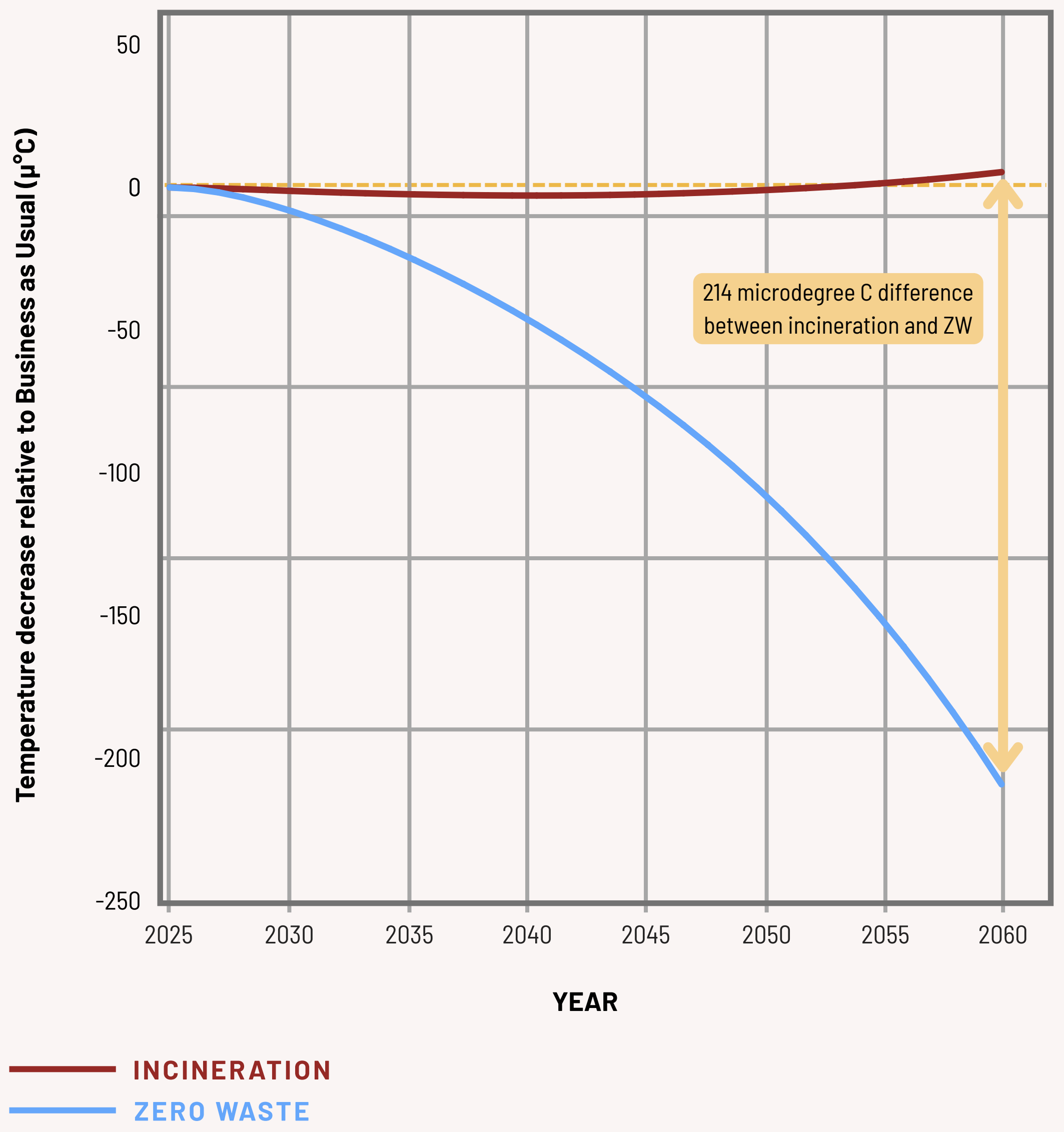
2060 climate results (relative to BAU):

- **Incineration:** +5.4 microdegrees °C
- **ZW:** -209.1 microdegrees °C

In Lagos, the modeled BAU scenario includes significant emissions from open burning, a common practice at the city's main dumpsite and in surrounding areas. Both alternative scenarios, incineration and ZW, reduce the volume of waste sent to open dumping, and reduce open burning proportionally. It should be noted that while open burning produces CO2 and harmful air emissions, it does reduce methane emissions from waste, thereby improving the performance of the BAU scenario strictly from a warming perspective.

The incineration scenario, in which the planned municipal incinerator would burn roughly 14% of Lagos' current waste, initially shows a modest improvement over BAU due to decreased methane emissions. Over time, however, CO2 emissions from incineration build up, waste volumes increase while incineration capacity remains static, and the trend reverses. By 2060, incineration results in a 5.4 microdegrees °C increase in temperature relative to BAU. In contrast, the zero waste scenario consistently outperforms both BAU and incineration across the entire modeled period. By 2060, the ZW pathway, centered around source separation and organics diversion, diverges significantly, achieving a temperature difference of more than 200 microdegrees °C below BAU. The overall warming differences reflect the compound effect of waste diversion, methane avoidance, and reduced open burning over time, and account for the equivalent of taking over 100 million cars off the road for one year (see methodology appendix for details). These results reinforce the value of source separation and organics diversion as more effective and enduring climate strategies than combustion-based approaches.

By 2060, zero waste avoids significant warming while waste incineration increases global temperatures in Lagos, Nigeria



ONE CAR REPRESENTS
1,000,000 CARS

LAGOS, NIGERIA

460M tonnes CO_2 saved is equivalent to 100M cars off the road!

Scenario	Waste management 2060	2060 climate results
BAU	Open dumping and open burning with minimal organics diversion and limited recycling	Baseline
Incineration with energy recovery	14% of waste sent to WTE incinerator starting in 2026*	+5.4 microdegrees °C
ZW	Source separation + composting 80% of organic waste and recycling 42% of total recyclables**	-209.1 microdegrees °C

**Incineration waste volumes based on the planned capacities of proposed incinerators, as reported in permit applications, planning documents, and environmental impact assessments*

***Composting and recycling targets based on waste stream composition and best-in-class recycling targets by material, and consultation with local experts. See methodology appendix for more details*

Quezon City, Philippines

Population: ~3 million
Waste generation: ~1.3 kg/person/day
Primary disposal methods (BAU):
Near universal collection; disposal at municipal sanitary landfills with landfill gas collection systems; high recycling rates supported primarily by waste pickers; minimal organics diversion at pilot and small scale sites

2060 climate results (relative to BAU):

- **Incineration:** -0.7 microdegrees °C
- **Zero Waste:** -23.5 microdegrees °C

In Quezon City, the ZW scenario again delivers a clear and consistent climate advantage over both BAU and incineration. From the start of the modeled period in 2026, ZW steadily reduces warming year after year, reaching a temperature reduction of approximately 23 microdegrees °C relative to BAU by 2060. The incineration scenario, in contrast, offers only a marginal climate benefit. The planned municipal incinerator, designed to burn approximately 25% of Quezon City's waste, initially delivers a slight reduction in warming compared to BAU. However, this benefit diminishes over time, with the incineration trajectory leveling off and eventually reversing direction by 2050, while the ZW pathway continues to widen the gap.

This reversal is primarily due to the fact that incineration capacity cannot scale up gradually with increasing waste volumes, while zero waste solutions can grow over time with flexible, scalable recycling and composting workforces, and small-scale infrastructure.

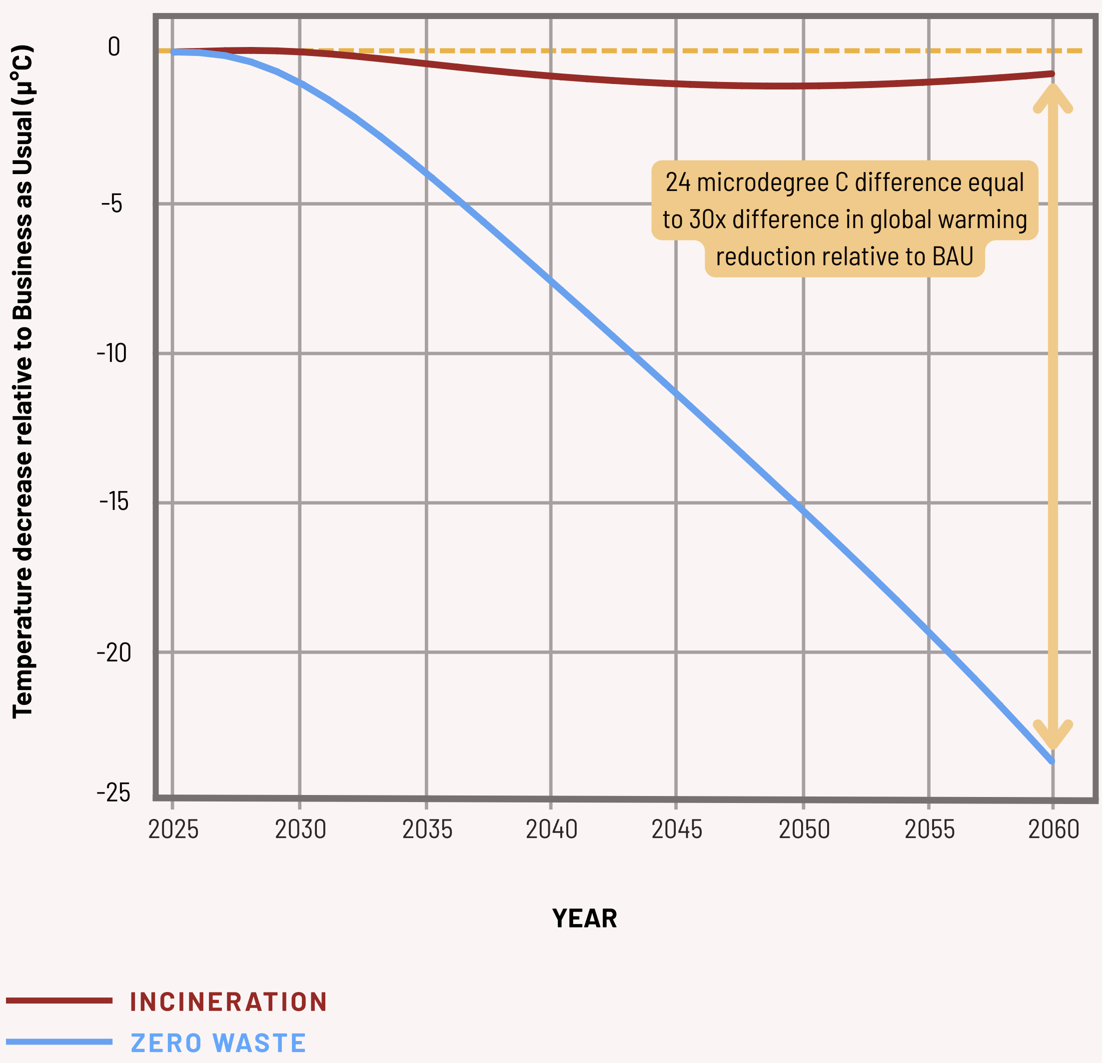
By 2060, the incineration pathway results in a warming difference of less than 1 microdegree C, making it roughly 30 times less effective than ZW over the same period. If the study period were extended and the existing trend continued, incineration would lead to net warming relative to BAU while the ZW scenario would continue to reduce warming relative to BAU. The amount of warming prevented by employing ZW strategies in this way is equivalent to that saved by taking over 11 million cars off the road for a year.

It should be noted that the BAU scenario includes landfill gas capture systems at its modeled landfills. While these systems can reduce methane emissions, they are subject to significant limitations, including lowered efficiencies over time, reliance on a steady supply of decomposable organic waste to generate gas, and maintenance to avoid leakage and fugitive emissions.[9,10] As landfills age or receive less waste, gas production declines, reducing the effectiveness of the capture system, sometimes putting the continuation of LFG capture systems, particularly those that use the captured gas to produce energy, at odds with waste reduction goals.[11,12] Meanwhile, the incineration pathway avoids some methane emissions by diverting organic waste from landfill, but substitutes them with fossil and biogenic CO_2 emissions that accumulate in the atmosphere and weaken the overall climate benefit.

The ZW pathway, on the other hand, avoids both methane and long-lived CO_2 emissions by diverting organics from landfill and combustion altogether. Despite the presence of LFG capture, it delivers the strongest performance, highlighting the value of upstream source separation and diversion.

Quezon City's results reinforce that ZW offers the most durable path to achieving warming impacts from the waste sector.

By 2060, zero waste is thirty times more effective in preventing global warming than waste incineration in Quezon City, Philippines



ONE CAR REPRESENTS
200,000 CARS

QUEZON CITY, PHILIPPINES

50.6M tonnes CO_2 saved is equivalent to 11M cars off the road!

Scenario	Waste management 2060	2060 climate results
BAU	Sanitary landfill with landfill gas capture and energy recovery, minimal organics management, strong recycling rates.	Baseline
Incineration with energy recovery	25% of waste sent to WtE incinerator starting in 2026*	-0.7 microdegrees °C
ZW	Source separation + composting 80% of organic waste and recycling 60% of total recyclables**	-23.5 microdegrees °C

**Incineration waste volumes based on the planned capacities of proposed incinerators, as reported in permit applications, planning documents, and environmental impact assessments*
***Composting and recycling targets based on waste stream composition, best-in-class recycling targets by material, and consultation with local experts. See methodology appendix for more details*

Barueri, Brazil

Population: ~300,000
Waste generation: ~0.8 kg/person/day
Primary disposal methods (BAU):
Disposal at a sanitary landfill without landfill gas capture; limited municipal recycling services; informal waste pickers contribute to material recovery, but organics remain largely unmanaged and are landfilled

2060 climate results (relative to BAU):

- **Incineration:** -3.5 microdegrees °C
- **Zero Waste:** -4.9 microdegrees °C

Barueri's BAU scenario includes nearly complete waste collection but no management of landfill methane. Both alternative scenarios (incineration and ZW) therefore show substantial reductions in methane emissions simply by diverting organics from landfill.

The incineration scenario modeled for Barueri, however, is atypical and represents an idealized case that is unlikely to be replicated elsewhere. Environmental impact reports and permit applications for the proposed incinerator indicate that the facility is intended to process waste from Barueri as well as neighboring municipalities. In order to account for this proposed oversized capacity, the scenario modeled in this analysis assumes that, beginning in 2026, 100% of Barueri's municipal waste is incinerated. This modeling choice is favorable to incineration and does not reflect the technical, legal, or regional constraints surrounding the project.

To begin, the scenario also assumes complete diversion of organics from landfill to incineration, introducing major technical challenges. Organic waste comprises roughly 50% of Barueri's waste stream and typically contains high moisture content, which lowers its energy potential and reduces combustion efficiency. In practice, incinerators handling high-organic-content waste often require supplemental fossil fuels like diesel or natural gas to maintain stable burn temperatures, undermining their claimed environmental and energy benefits. If the incinerator excludes wet organics to avoid these issues, it would fail to deliver meaningful methane reductions.

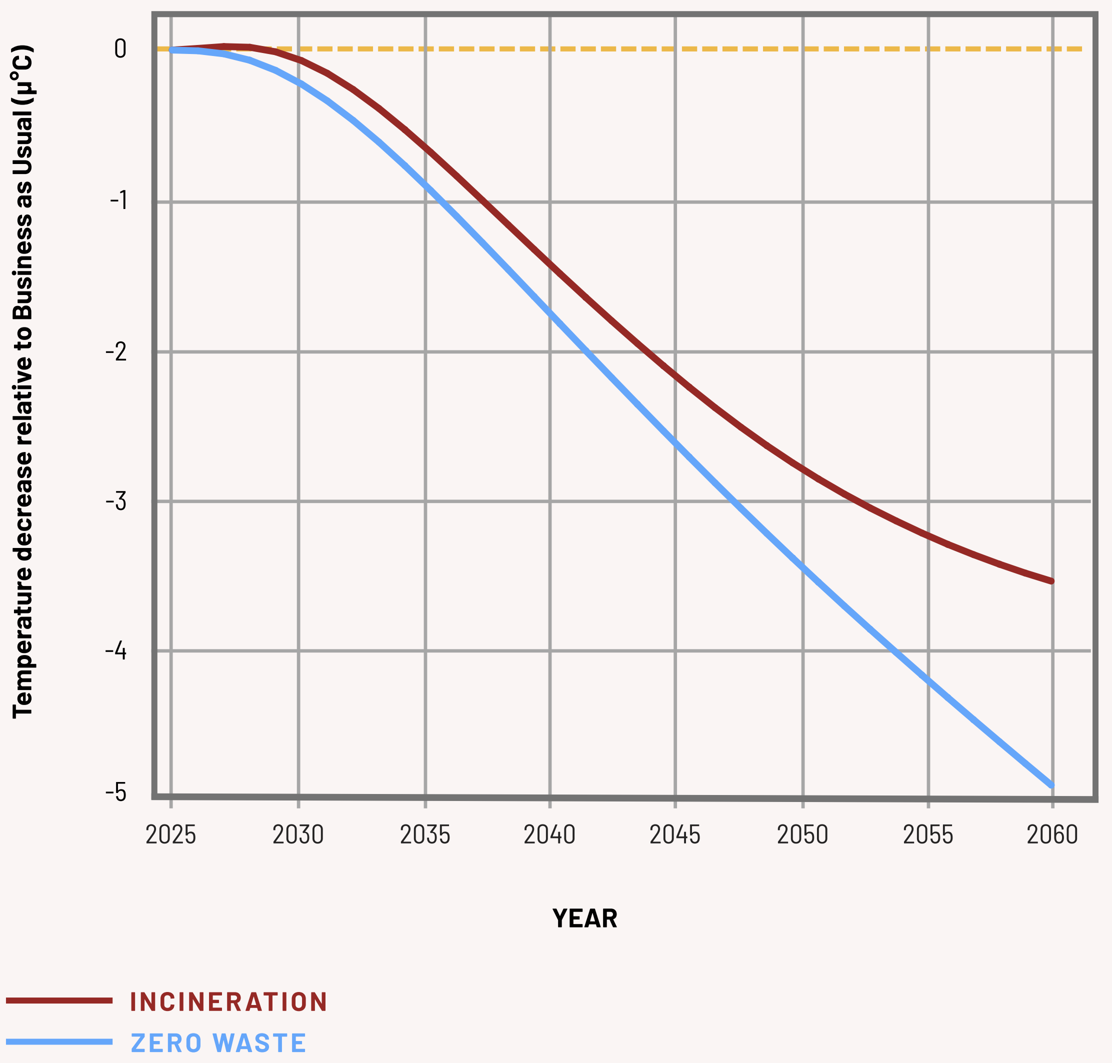
Additionally, the proposed incinerator as modeled here is legally inconsistent with Article 9 of Brazil's National Solid Waste Policy (PNRS Law No. 12,305/2010), which establishes a management hierarchy prioritizing waste prevention, reuse, and recycling. Energy recovery is intended only for residual waste that cannot be otherwise recovered. Estimates suggest that such non-recyclable residuals account for no more than 30% of municipal solid waste. Incinerating recyclable or organic materials contradicts the law's intent, risks undermining circular economy goals, and threatens the role of waste pickers in Brazil's inclusive recycling system.

Despite these limitations, the scenario is grounded in the permit applications and environmental documentation submitted for the proposed facility. It represents a simplified version of what, in practice, would be a technologically, logistically, and legally challenging, if not infeasible, undertaking. The analysis models the climate impact of burning the volume of waste specified in project documents and compares it against a BAU pathway and a ZW alternative. This simplification is intended to isolate the projected warming impact of the facility itself, without factoring in the real-world challenges of implementing such a system.

Even with all of these unusually favorable assumptions, ZW still outperforms. Both incineration and ZW result in steadily increasing climate benefits over time relative to BAU, but the gap between them begins to widen by the mid 2030s. By 2060, the ZW pathway achieves a temperature reduction of approximately 5 microdegrees °C, while incineration reaches only about 3.5 microdegrees °C lower than BAU, a divergence in performance that represents a 1.4 times improvement over incineration, and the equivalent of removing over 650,000 cars from the road for a year.

The relatively small difference observed in the early decades reflects the fact that both strategies eliminate methane emissions by diverting organic waste from landfill. As time progresses, however, the climate impact of incineration's continued CO_2 emissions begins to take over. Additionally, ZW solutions can scale up to meet increasing waste generation, while large incineration plants have a fixed capacity. This leads to a growing divergence throughout the modeled period. Extending the analysis beyond 2060 would likely reveal even larger long-term differences in warming impact and eventual reversal of the incineration trend.

Even in highly favorable scenarios for incineration, zero waste still outperforms on reducing warming in Barueri, Brazil



ONE CAR REPRESENTS
26,000 CARS

BARUERI, BRAZIL

2.99 tonnes CO_2 saved is equivalent to 650K cars off the road!

Scenario	Waste management 2060	2060 climate results
BAU	Landfill without landfill gas capture, minimal organics management and limited recycling	Baseline
Incineration with energy recovery	100% of waste sent to WTE incinerator starting in 2026*	-3.5 microdegrees °C
ZW	Source separation + composting 80% of organic waste and recycling 48% of total recyclables**	-4.9 microdegrees °C

**Incineration waste volumes based on the planned capacities of proposed incinerators, as reported in permit applications, planning documents, and environmental impact assessments*

***Composting and recycling targets based on waste stream composition, best-in-class recycling targets by material, and consultation with local experts. See methodology appendix for more details*

Overall Findings

Across all three cities, ZW scenarios consistently deliver greater climate benefits than incineration, avoiding significantly more warming by 2060. The magnitude of the overall temperature impact varies depending on the size of each city and their respective amounts of waste — Lagos manages far more waste than Quezon City, which in turn handles far more than Barueri — **but the trend is universal: ZW performs better in both the near and long term**.

Barueri's case in particular illustrates that even in a scenario that maximizes incineration's potential — total organics diversion, zero baseline mitigation, an unusually large facility, and exclusion of the technical and logistical challenges involved — zero waste is still the stronger long-term climate strategy. Achieving equivalent incineration strategies in cities like Quezon City or Lagos would require scaling incineration capacity by four to eight times what is currently planned — equivalent to building three additional incinerators in Quezon City and seven in Lagos — an infeasible proposition for most cities.

Overall, ZW outperforms incineration for several key reasons:

- **Methane versus CO_2 tradeoffs:** While incineration reduces methane emissions by diverting organic waste from landfills, it generates additional emissions of fossil and biogenic CO_2, which accumulate and drive long-term warming.
- **Displacement of recycling:** Incinerators rely on highly combustible recyclables such as paper, cardboard, and plastics for efficient combustion, putting them in direct competition with recycling efforts and ultimately reducing recycling rates.
- **Cumulative benefits of ZW:** ZW approaches reduce both methane and CO_2 emissions by minimizing landfill inputs, preserving materials, and avoiding combustion altogether. These benefits grow steadily over time, particularly as the long-term warming impacts of CO_2 take over in the modeled period.
- **Scalability of ZW:** ZW strategies scale effectively with city size because they can be expanded incrementally — adding more composting, recycling, or collection capacity as needed — allowing cities to adjust over time as waste volumes change. In contrast, incinerators and other capital-intensive facilities require large, upfront investments and are sized to handle fixed waste volumes for decades, making them inflexible and incapable of keeping up with methane emissions from increasing waste volume.

While this analysis focused on modeled temperature outcomes, it is important to recognize the broader co-benefits of ZW systems, such as job creation, public health improvements, and strengthened informal recycling systems. Globally, millions of waste pickers — who collect, sort, and sell recyclable materials without formal recognition — already play a critical role in keeping valuable resources out of landfills and incinerators.[13] Integrating them into formal waste systems not only recognizes the service they already provide, but also improves the performance of the waste system as a whole. Cities such as Buenos Aires (Argentina), Bengaluru (India), and Rabat (Morocco), that have contracted with waste picker cooperatives have achieved higher recycling rates and reduced landfill dependency, while also delivering better wages, access to healthcare, and safer working conditions for waste pickers.[14] By recognizing the expertise and contributions of waste pickers, ZW systems can build on existing infrastructure, create more jobs per tonne of waste than incineration or disposal,[14] and ensure that waste sector climate action is aligned with other societal benefits.

In contrast, incineration projects often require high upfront capital, long-term contracts, and steady waste inputs, locking cities into carbon-intensive systems for decades.[15] They also pose environmental and financial risks, especially for low- and middle-income cities where public resources are limited.[15]

More fundamentally, it is critical to assess the full climate impacts of waste sector interventions. As the Lagos case demonstrates, when viewed solely through the lens of methane mitigation, open burning performs nearly as well as incineration. However, both practices generate large amounts of CO_2 and hazardous air pollutants, undermining their long-term viability. This underscores the need for comprehensive evaluation methodologies that account for the full range of emissions and environmental and health impacts.

Beyond climate outcomes, ZW systems offer critical co-benefits that incineration-based approaches cannot match. They require less capital-intensive infrastructure, can be implemented incrementally, and create significantly more jobs per tonne of waste managed, particularly when informal waste workers are formally recognized and integrated into the system.[14] Composting and recycling reduce the burden of waste disposal while creating local economic opportunities and transforming discarded materials into new value streams, including recyclable commodities and compost for agricultural use. These advantages are especially important in cities like Lagos, Barueri, and Quezon City, where financial resources are limited, waste generation is rising, and informal labor plays a central role in the existing system.

In all three cities, the performance gap between ZW and the other scenarios widens over time. As waste volumes grow and the long-term impact of CO_2 emissions overtakes methane's short-lived forcing, the advantage of ZW becomes increasingly pronounced.

These findings suggest that **while incineration may provide some methane emissions relief, it is not a durable climate solution, even under the most favorable conditions for its performance. Zero waste, by contrast, offers sustained and scalable mitigation benefits aligned with long-term climate goals.**

Conclusion

This analysis confirms that ZW strategies represent the most effective pathway for reducing long-term warming from the waste sector. Across all three modeled cities, the ZW scenario consistently outperforms both BAU and incineration in terms of cumulative temperature increase through 2060. While incineration delivers reductions in methane emissions by diverting organics from landfills, those gains are outweighed by sustained emissions of fossil and biogenic CO_2. The result is a trajectory that most commonly leads to minimal reductions in warming relative to BAU.

ZW systems, by contrast, avoid the methane-CO_2 tradeoff by minimizing both types of emissions.

Through a combination of organics diversion, material recovery, and reduced dependence on landfills and combustion, these systems produce emissions profiles that steadily improve on BAU over time. As the FaIR model results show, these differences compound over time, with ZW achieving up to 9 times more avoided warming than incineration by 2060, equivalent to removing hundreds of thousands, to hundreds of millions, of cars from the road for a year. Additionally, it is important to note that the analysis focuses solely on modeled temperature outcomes — it does not capture the public health, environmental justice, or economic consequences of diverting recyclable materials from waste pickers to incineration.

Overall, ZW approaches are most aligned with climate commitments such as the Global Methane Pledge, the Paris Agreement, and the COP29 Declaration on Reducing Methane from Organic Waste. Unlike large, capital-intensive incineration projects, which lock cities into carbon-intensive waste flows over decades, ZW systems offer flexibility, lower financial risk, stronger alignment with long-term sustainability targets, and most importantly, greater reductions in global warming.

Methodology Appendix

Emissions Modeling with the Solid Waste Emissions Estimation Tool (SWEET)

The Solid Waste Emissions Estimation Tool (SWEET), developed by the U.S. Environmental Protection Agency, was used to generate scenario-specific annual emissions of methane (CH_4), carbon dioxide (CO_2), nitrous oxide (N_2O), and black carbon (BC) for each city. SWEET allows for detailed input of waste composition, treatment pathways, and site-specific conditions, and captures emissions reductions from interventions such as composting, recycling, and source separation. It accounts for the emissions impacts of landfilling, composting, anaerobic digestion, open burning, and incineration. Due to limited data availability and the assumption that these components remain constant across scenarios, emissions from transportation and handling equipment were excluded from this analysis. This omission is not expected to affect the relative differences in climate outcomes between scenarios, as academic literature indicates that transport and handling-related GHG emissions represent only a small share of total sector emissions. However, it is worth noting that diesel-based collection fleets can still be a significant local source of particulate pollution and other air quality impacts, even if their contribution to global warming is minor.

Waste composition and generation data inputs for SWEET were drawn from a combination of academic literature, municipal planning documents, and consultations with local experts. These included waste generation estimates, waste composition profiles, current treatment methods, diversion targets, and incinerator design specifications.

The three scenarios were defined as follows:

- Business as Usual (BAU): Disposal at landfills or dumpsites is the dominant waste treatment method, with limited recycling and composting by informal waste workers continuing at current rates. Waste is modeled as entering a single landfill in each city (unless otherwise specified below), which remains active through 2060.
- Incineration: A municipal incinerator is introduced in 2026. All waste that was previously recycled under BAU is assumed to be diverted to the incinerator to maintain sufficient caloric content for combustion. Each incinerator is modeled with a capacity factor of 80%, reflecting real-world performance of mass-burn waste incinerators reported in academic literature (see Table 1). Only electricity is utilized, not heat. Carbon emissions avoided through electricity generated by the modeled incinerators were estimated using default national grid emission factors from UNFCCC sources.[16] Electricity production factors for incinerators were sourced from academic literature on incinerator performance in jurisdictions with high organic waste content similar to the modeled cities.[17]

- Zero Waste (ZW): Beginning in 2026, source separation of waste is implemented at the household and municipal level, along with centralized composting to manage organic waste, and recycling programs to manage recyclables. Ambitious but realistic targets were established for both composting and recycling based on existing high-performance programs around the world (see Tables 2-6). Recycling targets were set for each material type based on achievable benchmarks from high-performing waste systems (see Tables 2-5 below), and these rates were applied to each city's specific waste composition profile to estimate total diversion. Existing recycling services performed by the informal sector were assumed to scale up over time with rising waste production. While overall recycling rates could be higher in practice, especially with strong policy support, this conservative approach provides a baseline for scenario comparison.
- Mechanical-biological treatment (MBT/MRBT) of residuals was not modeled due to its absence from SWEET, meaning some climate benefits of the ZW pathway may be underrepresented. City-specific diversion targets for organics and recyclables were developed based on local conditions and feasibility assessments (see assumptions for each city below).

For landfill and composting emissions, SWEET, like many waste emissions calculators, does not account for biogenic CO_2, the carbon dioxide generated from the decomposition or combustion of organic, non-fossil materials, as it is often considered carbon-neutral under national emissions inventory protocols. However, this analysis includes biogenic CO_2 to more accurately reflect the different carbon dynamics across waste treatment methods. While incineration and open burning release nearly all biogenic carbon as CO_2 immediately, landfilling and composting can result in long-term storage and release of some biogenic carbon. Excluding biogenic CO_2 therefore fails to capture the full warming implications of each strategy, particularly over long timescales where differences in CO_2 emissions become more significant.

Biogenic CO_2 from landfills or dumpsites resulting from methane oxidation (i.e., CH4 that oxidizes to CO_2 rather than being emitted as methane) was back-calculated based on SWEET's default oxidation factors. SWEET does not otherwise report landfill-derived CO_2 in cases where methane oxidation occurs, but this process represents a real contribution to atmospheric warming that should be included in life cycle assessments. Biogenic CO_2 directly emitted in landfill gas or from aerobic oxidation of waste was calculated using IPCC first order decay model methodology and figures for the degradable organic content of each city's waste sourced from SWEET's default values tab. Biogenic CO_2 emitted from composting was calculated using figures of degradable organic carbon (DOC) released as gas sourced from academic literature coupled with direct methane emissions figures provided by SWEET. As mentioned above, biogenic CO_2 from incineration is already included in the default emission factors provided and utilized by SWEET.

All scenarios assume a consistent annual increase in waste generation based on projected population growth rates for each city. While waste reduction strategies could further mitigate emissions, they were excluded from the current model to isolate the relative impacts of the different scenarios. It should be noted that waste reduction is also less compatible with incineration scenarios, which require sustained waste input to justify operational costs and infrastructure investment, potentially underestimating the benefit of ZW relative to incineration.

City-Specific Assumptions

Lagos, Nigeria

Lagos presents significant data challenges, including inconsistent population estimates and incomplete tracking of waste collection and treatment. To ensure consistency with available waste generation data, this analysis assumed a population of 21 million, which corresponds to a per capita generation rate of 0.62 kg/person/day, a figure calibrated to match reported daily waste generation of approximately 13,000 tonnes.[18]

Although nearly half of Lagos's waste is not collected in practice, the model assumed full collection of all generated waste in order to capture the total emissions impact of each scenario. This approach allows for a clearer comparison of treatment outcomes, and should not impact the accuracy of the analysis, as the emissions impact of uncollected vs. collected waste in SWEET is primarily driven by the use of waste handling equipment, which was excluded from the analysis and assumed to be similar across all scenarios.

Waste composition data was sourced from Lagos-specific studies, with particular attention to the proportion of organic materials in the waste stream. The primary dataset used provided a single aggregated value for organic waste, but because SWEET requires a distinction between food waste and yard waste, which have different decomposition rates and emissions factors, this fraction was disaggregated using average ratios from five household-level waste audits in Lagos.[18,19] Recycling rates in Lagos are difficult to determine due to the significant role of informal waste pickers, whose contributions are not systematically tracked. For this analysis, an estimated 6.7% recycling rate was used, an average of two figures: a 10% national estimate,[20] and a 3.4% Lagos-specific estimate.[21]

In the BAU scenario, nearly all waste is sent to a single open dumpsite, with open burning modeled as occurring exclusively at the site rather than in uncollected areas or households. This decision helps capture all of the emissions impacts of open burning in this scenario. No landfill gas capture or organics diversion is included. Open burning in both the incineration and ZW scenarios was reduced in proportion to the tonnage of waste diverted from the dumpsite to alternative treatment methods.

Quezon City, Philippines

Quezon City's existing recycling system is relatively well developed, with much of the diversion carried out by informal waste workers. Two landfills were modeled: one that operated from the 1970s until its closure in 2017, with landfill gas (LFG) capture installed in 2007; and a second that opened in 2007 and is modeled to remain active through 2060, with LFG capture installed in 2016. Because landfills continue to emit methane and CO_2 for years after closure, both landfills were included in the analysis, even though one stopped receiving waste before the scenario start year. This ensures that ongoing emissions from legacy waste are accounted for consistently across all scenarios. Open burning is negligible in Quezon City and was excluded from all scenarios. Composting and other organics treatment was also assumed to be negligible in the BAU scenario due to a low tonnage of organic waste being managed by existing pilot composting programs. The incineration scenario assumes the introduction of a municipal waste-to-energy facility in 2026, with a capacity based on the average of two capacity estimates (1,000 and 1,700 tonnes per day) provided by local experts. The ZW scenario models the composting of 80% of organics based on examples from other high-performing cities, and sets a recycling target of 60%, a realistic but ambitious increase over the estimated current rate of 48%. These targets were applied to Quezon City's waste composition to estimate total diversion tonnages.

Barueri, Brazil

As with Lagos, the analysis for Barueri focuses only on formally collected municipal solid waste (MSW). While this likely results in underreporting of total waste generation and emissions, it ensures consistency across scenarios and preserves the integrity of comparative results.

Barueri's MSW is currently sent to a landfill that also accepts waste from multiple jurisdictions across the São Paulo metropolitan region. The proposed regional incinerator is designed to process more waste than Barueri generates alone. For the purpose of this analysis, however, Barueri's waste composition and handling practices were used as the default for all waste to be processed by the incinerator, which includes 100% of Barueri's collected waste and additional tonnage from neighboring areas. This approach provides a realistic yet simplified estimate of incinerator performance while aligning with available city-specific data.

Detailed local data on the breakdown of organic waste into food and green waste categories was not available for Barueri. To meet SWEET's input requirements and distinguish between these two waste streams, values were estimated using an average derived from multiple international studies. The resulting assumption of 71% food waste and 29% green waste is based on sources from academic literature (see Table 8).

Climate Modeling with FaIR

Emissions outputs from SWEET were imported into the Finite Amplitude Impulse Response (FaIR) model to estimate temperature and radiative forcing outcomes. FaIR is a reduced-complexity climate model capable of simulating the atmospheric response to emissions trajectories over multi-decadal timeframes.

CH_4 and CO_2 emissions for each scenario and city were entered as annual values beginning in 2026. Additional emissions categories such as nitrous oxide (N_2O) and Agriculture, Forestry, and Other Land Use (AFOLU) were required for FaIR to run, but were set to zero to isolate the effects of the waste sector. This allows us to see the results directly attributable to the waste sector.

Initial conditions for the model were set to 2025 global values, including atmospheric CO_2 concentration, temperature rise since pre-industrial levels, cumulative CO_2 emissions, radiative forcing, and ocean heat content. Each scenario was run under three different climate sensitivity configurations, with final results presented for the "central" sensitivity case, as there was no qualitative difference between the sensitivity configurations.

To better reflect real-world uncertainty without overwhelming the signal of scenario differences, stochastic elements were included in the final model runs using a fixed random seed. This ensured that all three scenarios experienced the same stochastic variability, preserving comparability across outputs while simulating the natural variability of the climate system.

Temperature-car equivalencies

The final temperature differences between the incineration and ZW scenarios in 2060 were translated into a more accessible metric: the equivalent number of cars taken off the road for one year. This was calculated using values from academic literature for the warming impact of CO_2 emissions (0.44 °C per 1,000 gigatonnes of CO_2),[22] along with U.S. EPA estimates that a typical passenger vehicle emits 4.6 tonnes of CO_2 per year.[23] Because the EPA figure is based on driving patterns in the United States, where vehicle use is relatively high, these estimates likely understate the number of vehicles that would need to be removed in cities like Lagos, Barueri, or Quezon City to achieve equivalent emission reductions.

Table 1: Incinerator capacity factors

Incinerator capacity factors	Source
91%	IEA Bioenergy (2021) Waste-to-Energy and Social Acceptance: Copenhill WtE plant in Copenhagen https://www.ieabioenergy.com/wp-content/uploads/2021/03/T36_WtE-and-Social-Acceptance_Copnehhill-WtE-plant-in-Copenhagen.pdf
75%	Escamilla-García, P. E., Camarillo-López, R. H., Carrasco-Hernández, R., Fernández-Rodríguez, E., & Legal-Hernández, J. M. (2020). Technical and economic analysis of energy generation from waste incineration in Mexico. Energy Strategy Reviews, 31, 100542. https://doi.org/10.1016/j.esr.2020.100542
80%	Yakah, N., Kwarteng, A. A., Addy, C., Yirenkyi, M., Martin, A., & Simons, A. (2024). Techno-Economic Assessment of Municipal Solid Waste (MSW) Incineration in Ghana. Processes, 12(7), 1286. https://psecommunity.org/wp-content/plugins/wpor/includes/file/2408/LAPSE-2024.1651-1v1.pdf
76%	US Energy Information Administration (2025). Electric Power Monthly https://www.eia.gov/electricity/monthly

Incinerators require downtime for maintenance and repairs and therefore run at less than 100% of nameplate capacity. This analysis used an average of empirical capacity factors.

Recycling targets by material

Table 2: Best-in-class glass recycling rates

Glass recycling rate	Source
82% - South Africa	Department of Forestry, Fisheries, and the Environment (2022). Recyclability by Design for packaging and paper in South Africa https://www.dffe.gov.za/sites/default/files/legislation/2023-09/nemwa_packagingrecyclabilityguideline_g48845gon3604.pdf
92% - Survey of EU, UK, and Norway	Close the Glass Loop (2023) The performance of packaging glass recycling in Europe Insights from a Close the Glass Loop survey. https://closetheglassloop.eu/wp-content/uploads/2023/05/Packaging-Glass-Recycling-in-Europe-Performance-Report-2023.pdf

Table 3: Best-in-class paper recycling rates

Paper recycling rate	Source
80% - Germany	European Environment Agency (2022). Early warning assessment related to the 2025 targets for municipal waste and packaging waste https://www.eea.europa.eu/publications/many-eu-member-states/germany
73-78% - US	American Forest and Paper Association (2023). U.S. Paper and Cardboard Recycling Rates Continue to Hold Strong in 2022. https://www.afandpa.org/news/2023/us-paper-and-cardboard-recycling-rates-continue-hold-strong-2022
74% - South Korea	Cha, J., & Youn, Y. C. (2008). Paper recycling of South Korea and its effects on Greenhouse Gas emission reduction and forest conservation. *Journal of Korean Society of Forest Science*, *97*(5), 530-539. https://www.researchgate.net/profile/Youn-Yeo-Chang/publication/235931426_Paper_Recycling_of_South_Korea_and_its_Effects_on_Greenhouse_Gas_Emission_Reduction_and_Forest_Conservation/links/0fcfd5146adf22b830000000/Paper-Recycling-of-South-Korea-and-its-Effects-on-Greenhouse-Gas-Emission-Reduction-and-Forest-Conservation.pdf

Table 4: Best-in-class plastic recycling rates

All-plastic recycling rate	Source
21% - Japan	BBC (2022). Quitting single-use plastic in Japan https://www.bbc.com/future/article/20220823-quitting-single-use-plastic-in-japan
34% - South Korea	Davison, Tamara (2024) "How Much Plastic Actually Gets Recycled?" CleanHub. https://blog.cleanhub.com/how-much-plastic-is-recycled https://www.sea-circular.org/wp-content/uploads/2020/05/SEA-circular-Country-Profile_SOUTH-KOREA.pdf
41% - Europe, plastic packaging only, where packaging accounts for ~40% of plastic waste, effective rate 16%, assuming no recycling of other plastics	Eurostat (2024). 41% of plastic packaging waste recycled in 2022. https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20241024-3) https://www.oecd.org/en/about/news/press-releases/2022/02/plastic-pollution-is-growing-relentlessly-as-waste-management-and-recycling-fall-short.html

Table 5: Best-in-class metal recycling rates

Metal recycling rate	Source
70-97% - Aluminum across Mexico, US, Brazil	CanTech International (2022). On a mission to increase beverage can recycling rates. https://www.cantechonline.com/blog/28263/on-a-mission-to-increase-beverage-can-recycling-rates/, MundoLatas (2022) Recicla Latas Consolidates a Year of Work in Favor of Aluminum Cans Recycling in Brazil. https://mundolatas.com/en/recicla-latas-consolidates-a-year-of-work-in-favor-of-aluminum-cans-recycling-in-brazil/
75% - Aluminum, Europe	International Aluminum Journal (2025). New record in aluminium beverage can recycling. https://www.aluminium-journal.com/new-record-in-aluminium-beverage-can-recycling
80-85% - Steel, Europe	Packaging Europe (2022). APEAL reports 85.5% recycling rate for steel packaging in Europe. https://metalpackagingeurope.org/article/steel-packaging-europe-confirms-new-recycling-record; https://packagingeurope.com/news/apeal-reports-855-recycling-rate-for-steel-packaging-in-europe/8332.article

Table 6: Best-in-class composting rates

Organics diversion rate	Source
90% - Food waste, South Korea	Lee, E., Shurson, G., Oh, S. H., & Jang, J. C. (2024). The management of food waste recycling for a sustainable future: A case study on South Korea. *Sustainability*, 16(2), 854. https://doi.org/10.3390/su16020854
56% - Non-agricultural organic waste, Quebec 100% - Agricultural organic waste, Quebec	RecycQuebec. Organic Materials. https://www.recyc-quebec.gouv.qc.ca/sites/default/files/documents/bilan-gmr-2021-matieres-organiques-english.pdf

Table 7: Open burning rates to estimate open burning in Lagos' BAU scenario

Open burning rates	Source
40-65% of MSW - Lower-income countries	Pathak, G., Nichter, M., Hardon, A., Moyer, E., Latkar, A., Simbaya, J., ... & Love, J. (2023). Plastic pollution and the open burning of plastic wastes. *Global Environmental Change*, 80, 102648. https://doi.org/10.1016/j.gloenvcha.2023.102648
80% of uncollected waste - Nigeria	Okafor, C. C., Ibekwe, J. C., Nzekwe, C. A., Ajaero, C. C., & Ikeotuonye, C. M. (2022). Estimating emissions from open-burning of uncollected municipal solid waste in Nigeria. *AIMS Environmental Science*, 9(2). https://doi.org/10.3934/environsci.2022011
90% of uncollected waste - All Africa	Mebratu, D and Mbandi, A (2022). Open Burning of Waste in Africa: Challenges and opportunities. Engineering X (founded by the Royal Academy of Engineering and Lloyd's Register Foundation) and the United Nations High Level Champions (UNHLC). https://engineeringx.raeng.org.uk/media/u4mnsto5/open-burning-final-report_1.pdf

Table 8: Organic waste disaggregation figures for estimating food waste to green waste ratios in Barueri

Food waste to green waste ratio	Source
80/20 - Dar es Salaam	Bubegwa, S (2012) An Overview of Solid Waste Management in the City of Dar Es Salaam. https://www.globalmethane.org/documents/events_land_120910_12.pdf
69/31 - Mexico	Martínez, R. D. S., Jiménez, L. D., Juárez, O. A., & Hernández, S. C. (2024). Characterization of municipal solid waste with the perspective of biofuels and bioproducts recovery in Northeast Mexico. *Journal of Material Cycles and Waste Management*, 26(6), 3665-3680. https://link.springer.com/article/10.1007/s10163-024-02069-4
81/19 - Quezon City	Environmental Management Program (2018). Ecological Profile 2018. Chapter 5: Solid Waste. https://www.scribd.com/document/600881636/Ecological-Profile-2018
55/45 - Lagos	Olaoti, S. O. (2024). Plastic Pollution in Lagos State, Nigeria: Challenges and Sustainable Solutions. Open Journal of Environmental Research (ISSN: 2734-2085), 5(2), 1-15. https://doi.org/10.52417/ojer.v5i2.667

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