Emirates Biotech

Transforming Food Waste into Value:

The Sustainable Advantage for PLA-Integrated Composting in the UAE.

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Executive Summary

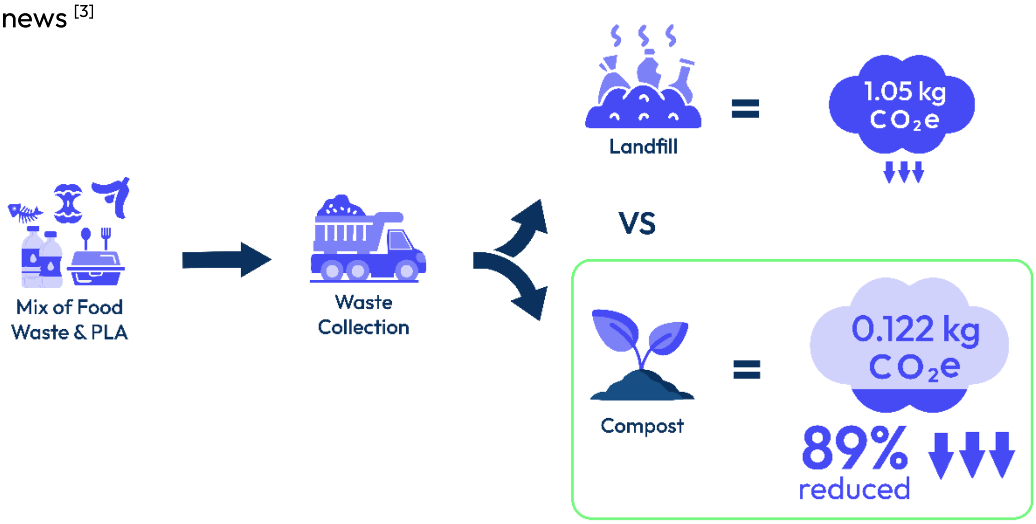
Food waste is one of the most significant pollutants of the total worldwide greenhouse gas emissions, approximated to be 8-10% [19]. With an estimated 2.25 million tons of food waste generated each year in the UAE alone, most of which is currently landfilled, this single waste stream contributes approximately 2.36 million tons of CO_2-equivalent (CO_2e) annually.

This white paper quantifies the environmental benefits of transitioning from landfilling to industrial composting for food waste management, using internationally recognized methodologies: the IPCC 2006 Guidelines (Vol. 5: Waste) and the U.S. EPA Waste Reduction Model (WARM) v16 (Dec 2023) under IPCC AR5 GWP_{100} values (CH_4 = 28, N_2O = 265). This means that methane is 28x more potent and N_2O being 265x more potent than CO_2 for GWP respectively.

Our study found that landfilling 1 kg of food waste emits 1.05 kg CO_2e, whereas industrial composting emits 0.122 kg CO_2e (assuming a 90/10 mix of food waste to PLA bioplastic based on our best estimate). This represents an 89% reduction in gross emissions.

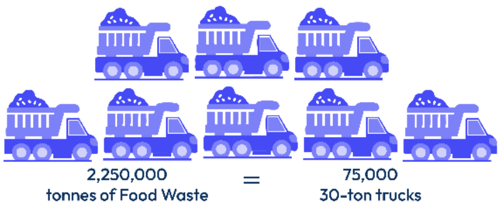
Annual food waste per capita in the UAE is cited at 197 kg (2019) by a study quoted by the UN's World Food Programme (WFP) [1]. With the UAE's 2025 population at 11.4 million at the time of writing [2], this implies a total of 2.25 Mt food waste and an emissions reduction of ~2.09 Mt CO_2e per year if all food waste is sent to composting (landfilling vs. composting).

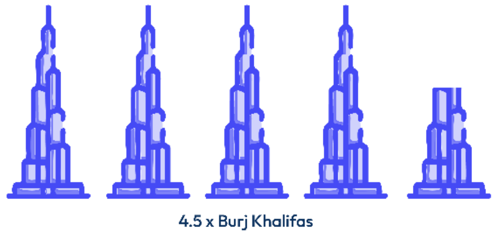
Important note: A 2024 MOCCAE report suggests an even higher figure of 3.27 million tons as sited by Arab news [3]



In real-world terms, this annual reduction is equivalent to:

- Powering 223,000 UAE homes for one year or,
- Removing 770,000 vehicles from the roads for a year in the UAE.
- The total amount of food waste in the UAE per year can be visualized to:





Composting further enables carbon-credit generation through two natural mechanisms: [6]

- Soil-carbon storage, where a portion of composted organic carbon remains sequestered in soil rather than returning immediately to the atmosphere; and
- Fertilizer offset, where compost displaces synthetic NPK fertilizers, avoiding the upstream emissions from their manufacture and field application.

When these verified credits (totaling −0.30 kg CO_2e per kg composted) are applied, the composting system becomes carbon-negative, i.e. it removes more CO_2e from the atmosphere than it emits. In this scoped comparison of landfill vs. compost end-of-life, composting one ton of food waste can offset an additional 0.16 t CO_2e beyond eliminating landfill emissions when we add up composting emissions to the net carbon credits.

The integration of compostable packaging materials (e.g., PLA bioplastics) strengthens this opportunity by allowing food and packaging waste to be composted together. This enables waste collectors to simplify collection and worry less about contamination, since food scraps and PLA items can be processed in the same stream. For example, if restaurants use PLA-based containers, cups, straws, and cutlery, any leftover food and these containers can be tossed into a single bin for composting as opposed to conventional plastic packaging which would require separate recycling streams for each material and clean segregation of food residues.

By adopting composting as the national treatment pathway for organics, the UAE could transform food waste from a major emitter into a carbon sink, directly advancing its Net Zero 2050 and Circular Economy 2031 objectives (which include diverting 75% of waste from landfills). This shift would also improve soil health, support local agriculture, and reduce reliance on imported fertilizers, delivering sustainability co-benefits alongside climate gains.

1. Introduction

Food waste represents one of the most carbon-intensive fractions of municipal solid waste (MSW) due to its rapid biodegradability and methane generation potential in landfills and accounts to 40% of the average household waste in the UAE [14]. The UAE's high food consumption rates, combined with warm climatic conditions that accelerate organic decomposition, make this an urgent environmental concern. According to recent assessments, food waste accounts for nearly 58% of total landfill-related emissions, underscoring the scale of its climate impact and the urgency of addressing it [5]. The UAE's landfill-dependent system where most organic waste is disposed of without energy recovery presents a major opportunity for emissions reduction under the national Net Zero 2050 strategy.

2. Methodology

This study applies internationally recognized life-cycle assessment (LCA) methodologies to quantify the CO_2e emissions from disposing of food waste via landfilling vs. composting. The analysis follows the IPCC 2006 Guidelines for National Greenhouse Gas Inventories (Volume 5: Waste) and the U.S. EPA WARM v16 (Dec 2023) model.[7] The model has considered landfill emissions from 10 different landfills across diverse environmental conditions to generate a more representative and statistically balanced average emission factor.

2.1 Functional Unit and System Boundary

The functional unit is 1 kg of food waste (wet weight) disposed of via either landfilling or industrial composting. The system boundary includes all direct process emissions and on-site energy use but excludes downstream “offset” credits such as soil carbon sequestration or fertilizer substitution for now. PLA biodegradation in landfills is assumed to be negligible as PLA biodegrades under industrial composting conditions, so we can assume PLA’s carbon emissions are locked within the material if landfilled. Biogenic CO_2 emissions are excluded per IPCC conventions, as they are considered part of the short-term biogenic carbon cycle.

2.2 Data Sources and Key Factors:

Data Component	Source	Notes
Landfill emission factor: 1.05 kg CO_2e/kg	EPA (2023) *Quantifying Methane Emissions from Landfilled Food Waste* [5]	Based on first-order decay methane modeling. Yields 34 t CH_4 per 907 t food waste (over 30 years).
Composting emission factor:0.122 kg CO_2e/kg	EPA (2023) *WARM v16 (Organic Waste)* [6]	Includes aeration energy and fugitive CH_4/N_2O.
CH_4 & N_2O GWP values	IPCC AR5 (2013) GWP_{100} *(AR5 WG1)* [7]	CH_4 = 28; N_2O = 265 kg CO_2e/kg. Used for all CO_2e conversions (consistent with WARM v16).

Unit conversion	*Standard conversion*	1 short ton = 907 kg (used to convert WARM factors to per kg).

Table 2-2 summarizes key emission factors and inputs.

3. Calculation of Emissions

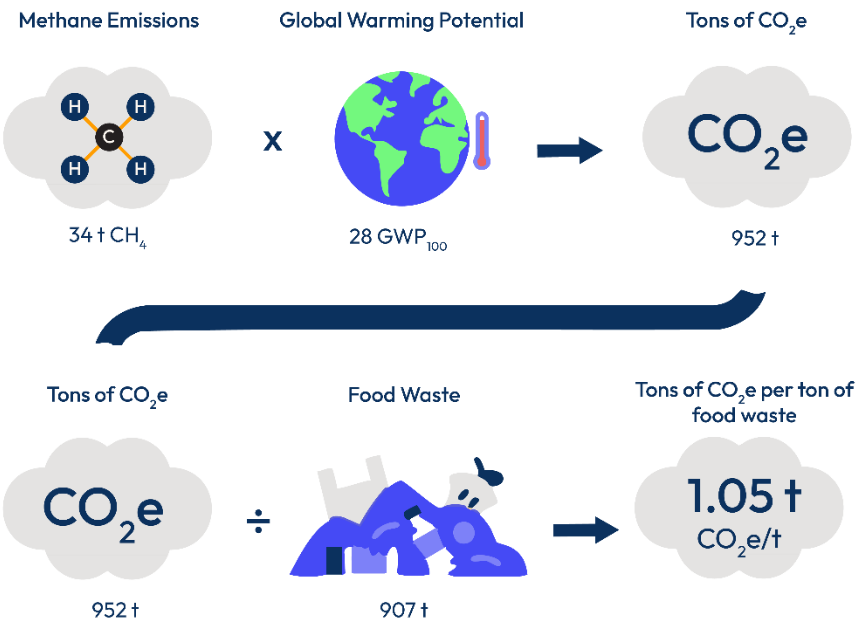
3.1 Landfill Emissions Methodology

Methane emissions from food waste in landfills were estimated using the First-Order Decay (FOD) model, which is the standard approach recommended by the U.S. EPA and IPCC for methane generation from organic waste. Instead of assuming waste decomposes all at once, the FOD model assumes biodegradable material breaks down gradually over decades, releasing methane at a decreasing rate as the carbon is consumed. This approach better reflects real landfill behavior for a better estimation.

Key model parameters for the landfill scenario include a 75% gas-capture efficiency (methane collected for flaring or energy recovery) and 25% oxidation of the residual methane passing through the soil cover. This assumption is applied to the UAE in this study; however, due to the limited number of studies on UAE landfills and our understanding of current infrastructure, actual methane capture rates are likely significantly lower. Using these conditions and waste decay characteristics, EPA's 2023 analysis determined that 34 tons of CH_4 are emitted (un-captured) per 907 tons of food waste landfilled [5]. (907 tons is used here as the calculations were done per US ton, we are converting to imperial units)

Note: The value of 1.05 kg CO_2e/kg for landfilled food waste is taken from EPA's 2023 methane quantification study, which estimates fugitive methane emissions from food waste. Lower factors reported in WARM (e.g., 0.66 kg CO_2e/kg) incorporate credits for landfill-gas energy recovery and other system-level assumptions typical of U.S. infrastructure; these are not yet representative of UAE landfill conditions, so the higher methane-only value was selected as a conservative and regionally appropriate estimate.

To express this in CO_2e terms:



This 1.05 t CO_2e/t represents the lifetime GHG emissions from 1 t of food waste in a landfill, which is equivalent to the same value in kg for 1kg of material landfilled. We use the same per-kg basis for the composting scenario for an apple-to-apple comparison. It is important to note that the landfill emission data referenced in this paper is based on the AR4 model. In this study, we have applied the AR5 model to ensure methodological consistency with the composting analysis, which also uses AR5 global warming potential values.

3.2 Composting Emissions Methodology

Industrial composting occurs under aerobic, managed conditions designed to stabilize organic matter while minimizing methane formation. (Biogenic CO_2 from decomposition is not counted, as it is part of the natural short-term carbon cycle per IPCC guidance.) [6] CH_4 is formed in anaerobic sections of the compost, but it is largely oxidized in the aerobic sections of the compost. The estimated CH_4 released into the atmosphere ranges from less than 1% to a few per cent of the initial carbon content in the material. [16]

Method: Emissions were quantified using EPA's WARM v16 (Dec 2023) under the AR5 GWP_{100} framework (CH_4 28; N_2O 265). The boundary includes:

- GHG emissions released during composting
- Operational energy use (electricity/diesel)

Downstream credits like soil carbon sequestration or fertilizer displacement are excluded here (they are addressed separately in Section 5).

Gross Composting Emissions: Table 3-1 breaks down the modeled composting emissions factors for food waste and for PLA (polylactic acid compostable plastic), based on WARM. All values are per unit of material processed.

Food Waste		
Process CH_4 + N_2O	0.088	Total Gross Emission
	+	**0.12 kg CO_2e/kg**
Electricity + diesel (operations)	0.033	

PLA (PolyLactic Acid)		
Process CH_4 + N_2O	0.110	Total Gross Emission
	+	**0.14 kg CO_2e/kg**
Electricity + diesel (operations)	0.033	

Total Mixed Emissions Calculation
$\text{Total}_{mix} = (f_{food} \times 0.12) + (f_{PLA} \times 0.14)$

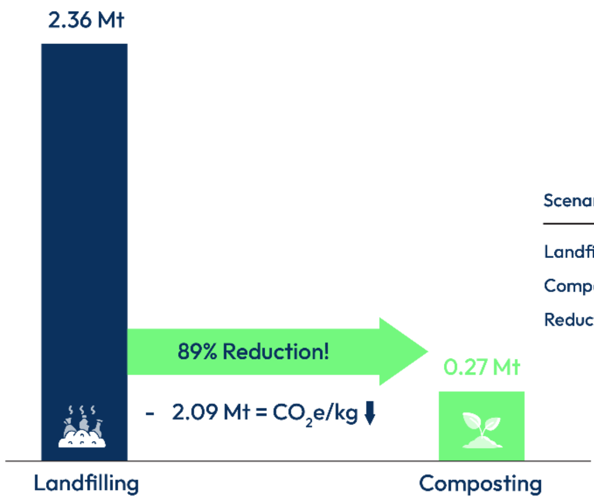
Table 3-1. Table showing the emissions split for each material under composting conditions [6]

For mixed streams of food waste plus PLA, emissions are a weighted average. For example, a 10% PLA mix yields 0.122 kg CO_2e/kg (versus 1.05 kg for landfilling – an 89% decrease). This shows that composting 1 kg of waste emits on the order of 0.122 kg CO_2e.

Interpretation: Roughly 70% of composting emissions come from fugitive CH_4/N_2O, while 30% come from energy use based on the table above. Higher PLA content slightly increases energy needs (presumably longer aeration), but total emissions stay well below 0.14 kg CO_2e/kg. Compared with landfilling (1.05 kg CO_2e/kg), composting reduces gross emissions by 89% *before* any credits for soil carbon or fertilizer offsets.

4. Results: UAE Food Waste Emission Comparison

The UAE generates approximately 2.25 million tons of food waste per year. Table 4-1 quantifies the annual GHG emissions from the current landfilling practice versus a shift to industrial composting (assuming a 10/90 PLA to food waste scenario).



Scenario	Emission Factor (kg CO_2e/kg)	Annual Waste (Mt)	Total Emissions (Mt CO_2e/yr)
Landfilling	1.05x	2,25	2.36
Composting	0.122x	2,25	0.27
Reduction (Compost vs Landfill)	-	-	-2.09

Table 4-1. Annual GHG Emissions: Landfill vs. Composting, rounded to two decimal points (UAE Food Waste)

Interpretation: Diverting the UAE's 2.25 million tons/year of food waste from landfills to composting would cut gross GHG emissions from 2.36 Mt CO_2e down to 0.27Mt CO_2e per year – an 89%

reduction in process emissions. Under these conditions, about 2.09 Mt CO_2e are avoided annually (before applying any offset credits).

This corresponds to a gross reduction of 2.09 Mt CO_2e/year, nearly eliminating the emissions currently produced by landfilling. In other words, a national transition to composting could turn the food-waste sector from a major emitter into a net carbon sink, directly supporting the UAE's Net Zero 2050 Strategy. This estimate excludes additional benefits like soil carbon sequestration and fertilizer substitution, which would further lower net climate impact and could even render composting carbon-neutral or carbon-negative under UAE operating conditions. Although it is unrealistic to assume that all food waste and its associated packaging will be composted, it is important to emphasize that even partial adoption would yield a very substantial emissions reduction.

5. Carbon Credit Potential and Net-Zero Implications

In addition to direct process-emission reductions, composting can generate carbon credits via two primary mechanisms:

1. Soil Carbon Storage: A portion of the organic carbon in finished compost remains in the soil for decades (rather than quickly oxidizing to CO_2). This acts as a removal credit. Based on literature and WARM defaults, this credit is about −0.18 kg CO_2e per kg of waste composted (equivalent to −0.16 MT CO_2e per short ton).

2. Fertilizer Offset: Compost replaces some synthetic fertilizer use, avoiding the upstream GHG emissions from producing and applying those fertilizers. This credit is about −0.12 kg CO_2e per kg of waste (−0.11 MT per short ton).

Carbon Credit Equivalent (kg CO_2e/kg)

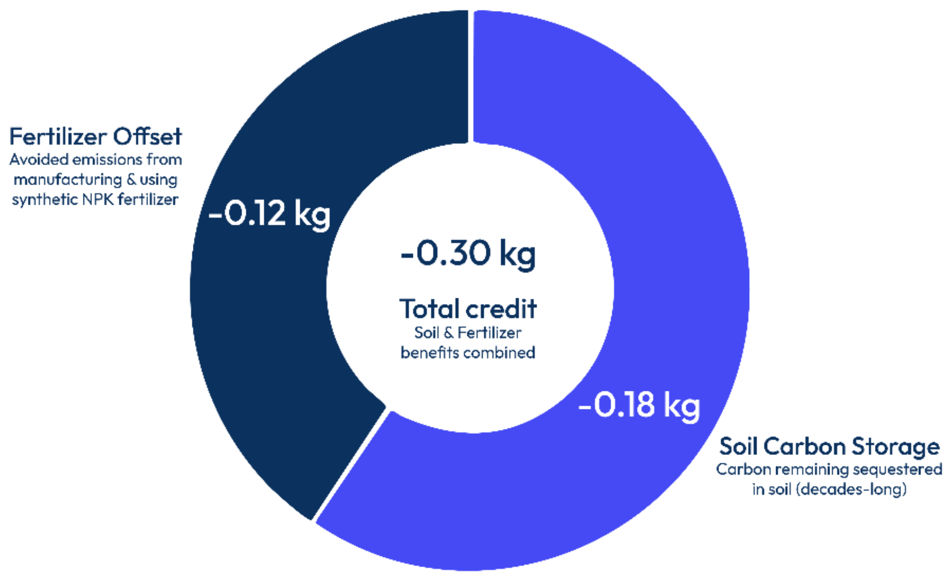


Table 5-1. Carbon Credit Factors from Compost Use (per short ton and per kg) [6]

Using these credit factors, we can assess the net emission balance for composting in the UAE. Applying the total −0.30 kg/kg credit yields a net of approximately −0.16 kg CO_2e per kg waste. In other words, when accounting for end-use benefits, composting *sequesters more carbon than it emits* – it becomes carbon-negative on a life-cycle basis.

6. Climate Equivalents

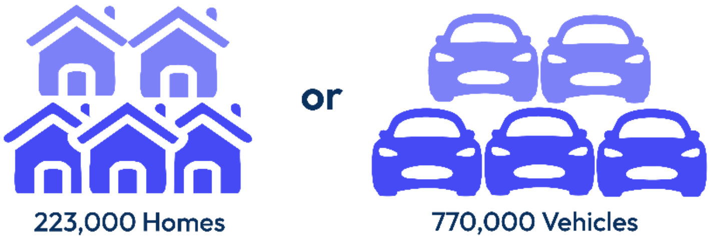
To put the annual benefit of diverting UAE food waste to composting into perspective: an avoided 2.09 Mt CO_2e per year (gross, excluding offsets) can be visualized in terms of everyday emissions equivalents. We use standard conversion factors from the U.S. EPA Greenhouse Gas Equivalencies Calculator (2024), the International Energy Agency (IEA 2023), the FAO (2022), and the ICAO (2024):

- Electricity use: Based on 2017 data, Dubai households consumed 12,795 GWh across 551,077 [20] homes, an average of 23,200KWh/yr per home [8]. At DEWA's emissions factor of 0.4041 kgCO_2e/kWh [9], this equals 9.38 tCO_2e per home per year.

Our composting impact would offset the electricity-related emissions of approximately 223,000 households annually.

- Passenger vehicles: With average emissions of 2.3 kgCO_2e/liter [10], and a driving pattern of 20,000 km/year at a generous 17 km/l efficiency, each car emits 2.7 tCO_2e/year.

  Our emissions savings would be equivalent to removing 770,000 gasoline cars from UAE roads each year.



7. International Practical Evidence

Industrial composting isn't a theoretical best-case, it's already working in Europe, and one of the clearest examples comes from Italy. Milan was the first major city in the world to implement mandatory, city-wide household food-waste separation across both residential and commercial streams with the help of compostable bags. By 2014, just two years after roll-out, 90kg of organic waste was being collected per person. Crucially, the system achieved contamination levels below 5%, enabling the production of high-quality compost used in regional agriculture. The report highlights that each ton of separately collected food waste, when composted, prevents the release of methane that would otherwise be generated in landfills, reinforcing the climate case for biobased materials and integrated organics recovery.[11] [12]

The broader impact of this collaboration is captured in *PBPC's "Plant-Based Leaders: Novamont" (2023)* analysis: for every 1.5 kg of food waste collected and composted, approximately 2.6 kg of CO_2e emissions are avoided. The avoided emissions come directly from the methane that never forms under aerobic composting conditions. This ratio, a positive carbon balance exceeding 1:1, demonstrates that even before crediting soil-carbon storage, composting already yields significant net climate gains.[13]

Together, these sources form one of the strongest empirical cases for organics diversion. Milan proves the logistical side, full participation, low contamination, and operational reliability.

8. Burning Food Waste

Burning food waste is inefficient because its high moisture content drastically lowers its caloric value. In controlled combustion, the moisture content of wasted food typically ranges from 67–80% [15], meaning that most of the energy released during burning is consumed in evaporating water rather than generating usable electricity. Feedstocks that include wasted food, with a high moisture content and low heating value, may require supplemental fuel or pre-drying for complete combustion.

Burning food waste is energetically wasteful because of its low caloric value, whereas composting transforms that same organic material into a nutrient-rich resource, and landfilling simply locks it away while releasing methane.

Material bound for landfill at the Bee'ah facility in Sharjah, U.A.E. Photographer: Christopher Pike/Bloomberg.

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9. Policy and Infrastructure Implications

Transitioning to nationwide composting for organics aligns with the UAE's Net Zero 2050 strategy and supports the Circular Economy Policy 2031. Integrating PLA-compatible composting infrastructure can deliver measurable climate benefits while reducing landfill dependence.

Key recommendations:

1. Establish regional composting hubs near cities
2. Mandate source-separated organics in the hospitality and residential food sectors
3. Certify compostable packaging that can compost with food on a large scale (e.g. PLA) under UAE standards
4. Promote compost use in soil rehabilitation and desert greening; and
5. Incentivize large composting projects for verified carbon credits to monetize the avoided emissions and soil carbon gains and start-ups in the waste management space to help meet UAE's environmental goals.

9.1 Composting Certifications

Certified compostable materials play a critical role in ensuring that organic waste streams remain clean, efficient, and compatible with industrial composting systems. Products that meet internationally recognized standards, such as EN 13432 or ASTM D6400, are designed to fully biodegrade under controlled composting conditions without leaving behind toxic residues, microplastics, or persistent fragments. Certification is essential because non-certified "biodegradable" plastics often fail to break down, leading to contamination that reduces compost quality, increases processing costs, and undermines trust in organics programs. By allowing only certified compostable products into the food-waste stream, the UAE can safeguard compost quality, support efficient processing, and ensure that packaging materials contribute positively to a circular, organics-based waste system rather than becoming a contaminant.

Certified compostable products must meet four core criteria:

- Biodegradation: At least 90% conversion to CO_2 within 180 days under industrial composting conditions.
- Disintegration: After 12 weeks, no more than 10% of the material may remain as fragments >2 mm.
- Compost Quality: No negative effects on plant growth or soil health.
- Low Toxicity: Heavy metals and hazardous substances must be below strict limits.

These requirements ensure that certified compostable packaging fully breaks down in the composting stream, avoids contamination, and produces clean, high-quality compost. [21]

9.2 Organic Waste Infrastructure

A well-designed organics system does not require food waste and certified compostable packaging to be separated. When materials meet recognized compostability standards, they can be collected together and processed through the same industrial composting pathway. This simplifies collection, reduces handling costs, and avoids the inefficiencies created by trying to separate food residues from their packaging. International programs, most notably Milan's as mentioned above, show that allowing certified compostables into the organic stream improves capture rates and keeps contamination low, while ensuring that the resulting compost remains high in quality.

9.3 Composting and Local Agriculture Alignment

Composting directly supports MOCCAE's vision for sustainable local agriculture and food security by converting organic waste into a high-value soil that enhances productivity in arid conditions like the UAE's climate. The compost produced restores organic matter and microbial life, improving soil structure, water retention, and nutrient cycling, all critical for achieving higher yields with lower irrigation demand. This aligns with the Ministry's emphasis on reducing reliance on imported fertilizers, promoting self-sufficiency, and minimizing the environmental footprint of food production[17]. By integrating composting into local farming systems, the UAE can close the loop between waste management and food production, which would turn unavoidable food waste into a regenerative input that advances the national goals of climate resilience, resource efficiency, and circular agriculture outlined by MOCCAE.

9.4 Industrial Compostability vs. Home Compostability

While some compostable packaging products pursue home-compostability certification, this has limited real-world environmental value because home composting is practiced by only a small minority of households and is not how organic waste is managed at scale. In most countries, including the UAE, food waste is collected centrally and treated through municipal systems, not backyard compost bins.

As a result, packaging designed primarily for home composting does not meaningfully contribute to waste diversion or emissions reduction. In contrast, industrial compostability aligns with actual waste-management infrastructure, enabling food waste and certified compostable packaging (such as PLA) to be collected and processed together in controlled facilities. From a system-level perspective, prioritizing industrial compostability and investing in the corresponding infrastructure is far more effective than focusing on home compostability, which remains small, difficult to scale, and largely disconnected from how waste is handled in practice.

10. Conclusion

This study demonstrates that shifting UAE food waste from landfilling to industrial composting offers one of the most immediate, scalable opportunities for cutting national GHG emissions. Using EPA WARM v16 (Dec 2023) with IPCC AR5 factors, diverting 2.25 million tons/year of food waste from landfills to composting would reduce gross emissions from 2.36 Mt to 0.27 Mt CO_2e per year (an 89% reduction).

Beyond process efficiency, composting unlocks additional carbon reductions via soil-carbon storage and fertilizer offsets. Together, these credits *exceed* the remaining emissions – meaning composting becomes a net carbon-negative solution that transforms food waste into a long-term carbon sink.

Incorporating compostable packaging with PLA further enhances this opportunity by allowing mixed food-and-packaging waste to be processed together. This synergy between bio-based materials and organic recycling is a key enabler of the UAE's transition toward a circular, low-carbon economy.

If scaled nationally, the shift to composting could deliver nearly 2 Mt CO_2e savings annually, equivalent to removing almost 800,000 cars from the road or powering 223,000 homes for a year.

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