GAIA Technical Guidance Series for Policymakers
and Financiers on Fast Action on Waste and Methane

Municipal Strategies for Organic Waste

A Toolkit to Cut Methane Emissions

Executive Summary

Municipal Strategies for Organic Waste: A Toolkit to Cut Methane Emissions is the 1st of the GAIA Technical Guidance Series for Policymakers and Financiers on Fast Action on Waste and Methane. Following commitments within the Global Methane Pledge and the COP29 Declaration to Reduce Methane from Organic Waste (ROW declaration), signatory countries have pledged to significantly reduce waste methane emissions by 2030. While this will pose an increase of political and financial resources driven towards the waste sector, there is a need to ensure the implementation of measures to reduce methane emissions is aligned with the Environmental Justice Principles for Fast Action on Waste and Methane.

Organic Waste is a critical focus for methane reduction. Municipal solid waste is a major source of methane emissions, yet it also presents one of the most cost-effective opportunities for rapid climate action. Waste management policies such as waste separation at source, recycling, and composting could cut total emissions from the waste sector by 84%—or more than 1.4 billion tonnes—equivalent to taking all motor vehicles in the U.S. off the road for a year. Composting, bio-stabilization, and biologically active covers for dumpsites can reduce waste methane emissions by up to 95%. Even simple measures like waste segregation and organic composting can achieve a 62% reduction in landfill methane emissions.

This toolkit introduces six key strategies to help municipalities reduce methane emissions from organic waste: animal feed, composting, vermicomposting, anaerobic digestion, black soldier fly processing, and landfill biocovers. The primary objective is to prevent organic waste from reaching landfills by prioritizing diversion and resource recovery. Recognizing that some waste may still end up in landfills, the toolkit also includes landfill biocovers as an essential solution to mitigate methane from existing waste. Each solution is evaluated in terms of infrastructure needs, regulatory requirements, necessary skills, and social, economic, and environmental impacts. This analysis provides municipal officials with clear information on enabling conditions and practical pathways for context-specific implementation.

As key takeaways, the toolkit highlights that organic waste, when managed as a resource, offers municipalities a powerful opportunity to support local agriculture, generate energy, create jobs, and achieve significant methane reductions. The true value of organic waste management technologies lies in their long-term benefits—protecting the environment, improving public health, closing nutrient cycles, and building community resilience—even when immediate market returns may not cover all system costs. Municipalities should prioritize prevention and reduction, redirect organics to secondary markets or animal feed where possible, and return nutrients to soils through composting or energy recovery, with landfilling as a last resort due to its high methane emissions and nutrient loss.

Effective organic waste management starts with strong source separation, regular collection systems, and active community engagement, including the participation of waste pickers and local groups. By choosing context-appropriate, decentralized strategies and optimizing logistics to treat waste as close to its source as possible, municipalities can reduce costs, minimize contamination, and create inclusive job opportunities. Ultimately, integrating public participation with tailored technical solutions transforms organic waste from a challenge into a valuable asset for healthier, more sustainable, and equitable communities.

Index

Introduction

Reducing methane emissions from landfills is one of the most impactful strategies municipalities can pursue to address climate change. Methane is generated when organic waste such as food waste and garden clippings break down in landfills and dumpsites under environments with restricted presence of oxygen. Organic waste management is therefore a key climate mitigation tool for local governments, with additional co-benefits for public health, soil regeneration, and resource recovery. Source separation of organic discards, coupled with composting, bio-stabilization of residual waste and biologically active cover for landfills and dumps can reduce solid waste methane emissions by as much as 95%[1]. While this document focuses on treatment options, it is important to remember that waste prevention is the most preferable strategy in terms of cutting methane emissions and should be considered in any waste management policy and program.

To support municipal decision-makers, this guide offers a comparative and practical framework to evaluate five viable and mature strategies: composting, vermicomposting, anaerobic digestion, black soldier fly (BSF), and landfill biocovers. Rather than offering step-by-step technical instructions, this document supports policy and planning by outlining essential factors such as infrastructure needs, permit and regulatory considerations, environmental performance, cost-effectiveness, and scalability at small, medium, and large scales.

Essential elements for successful implementation include source separation and integration of the informal sector. Both are grounded in Environmental Justices Principles - respecting planetary boundaries to ensure intergenerational equity, valuing all waste pickers and waste workers, enhancing inclusion and building on local knowledge, responding to pollution and environmental harm with accountability, and supporting holistic solutions through systems change. These approaches not only maximize processing efficiency and quality, but also reduce contamination and operational costs. Integrating these aspects further promotes public education, advances social equity, and fosters community-supported collection systems.

Common implementation challenges, emerging opportunities, and real-world case studies are explored, emphasizing the importance of clear system design and strong community engagement. With the right tools and approaches, municipalities can turn food waste into a valuable resource while advancing local and global climate goals.

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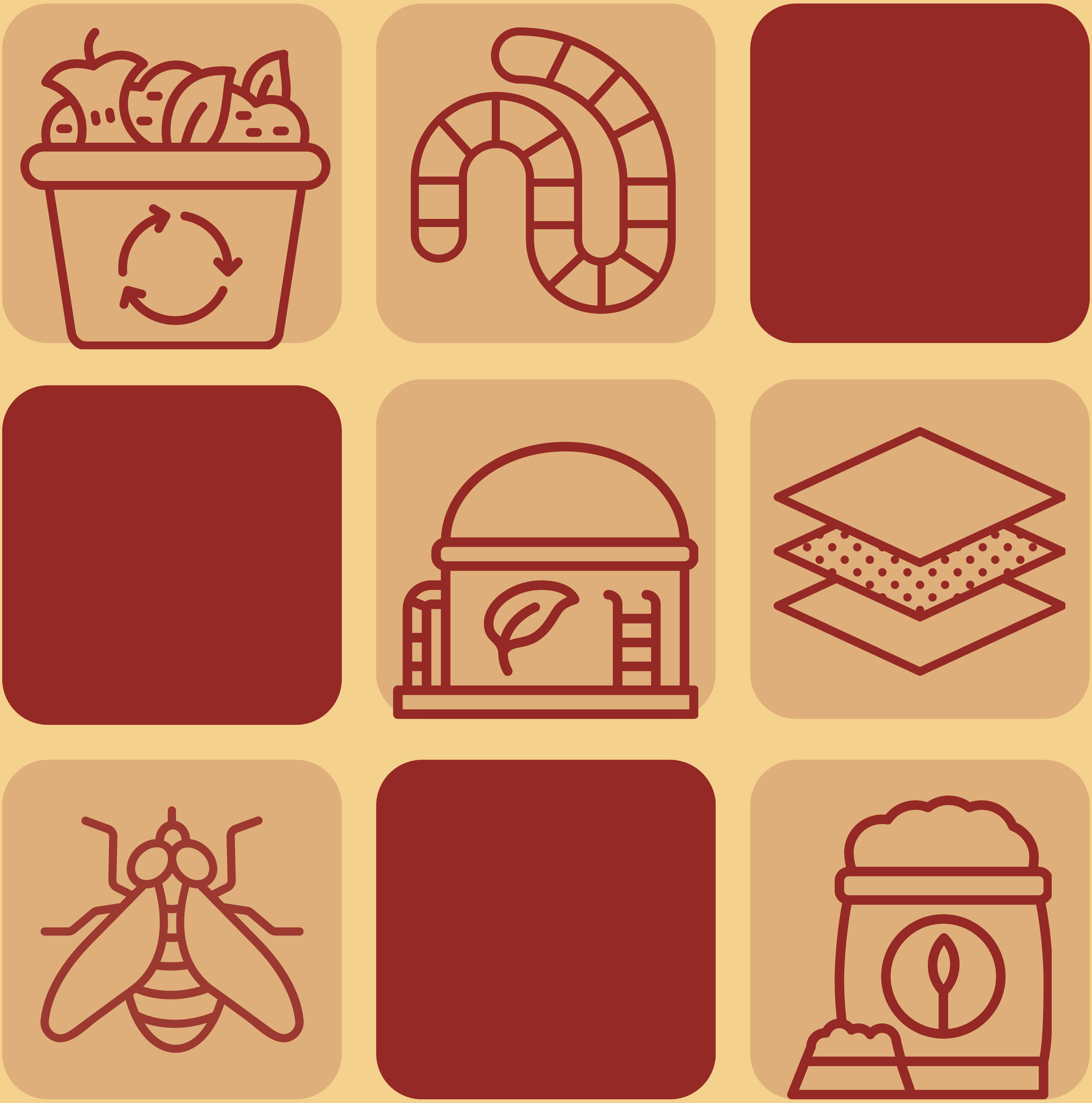
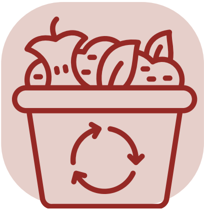
[1] Methane Matters: A Comprehensive Approach to Methane Mitigation. 2022. Changing Markets Foundation, Environmental Investigation Agency, Global Alliance for Incinerator Alternatives.



Strategies



Composting

DEFINITION

Controlled biological decomposition of organic materials—such as food scraps, yard trimmings, and other biodegradable waste—**into a stable, nutrient-rich product known as compost.**

The process occurs primarily under aerobic conditions, where microorganisms break down organic matter in the presence of oxygen, generating heat, reducing volume, and stabilizing nutrients. While natural decomposition can occur slowly and inconsistently, composting optimizes the environment for microbial activity by managing factors such as moisture, oxygen, temperature, and the carbon-to-nitrogen ratio. Sources: (21), (22), (23), (31)

OUTPUTS

The primary output is a stabilized organic material—compost—that can be used as a soil amendment.

Mature compost typically has a crumbly texture, dark color, and an earthy smell, with a carbon-to-nitrogen ratio below 20, pH values between 7 and 9, and increased concentrations of nitrogen, phosphorus, and potassium compared to raw feedstock. Humic and fulvic acids in compost enhance nutrient retention and soil structure, while the germination index (GI) is often used to verify maturity, with values above 80% considered stable and safe for application. Compost can be used directly in agriculture, landscaping, or urban green areas. Liquid extracts such as compost tea are also derived from mature compost for localized soil and plant treatment. Sources: (21), (23), (26), (31)

WASTE INPUT CONSIDERATIONS

All organic materials for composting must be clean and properly separated at the source to minimize contamination. At a small scale, inputs typically come from kitchen scraps and garden trimmings. At a medium scale, sources include markets, offices, schools, and similar facilities. For large-scale or industrial composting, organic material is collected from municipal waste streams, markets, and food industries, where maintaining high volumes of clean inputs often requires mechanical sorting.

COMMUNITY ENGAGEMENT

Composting can engage communities at both the household and neighborhood levels. Household composting empowers individuals, while community composting encourages collective action. Success depends on strong local leadership, and social cohesion. Source separation is key for high quality composting, making community awareness and participation critical. Source: (31)

Worm Composting

DEFINITION

Biological process that uses earthworms—primarily *Eisenia foetida* and *Eudrilus eugeniae*—**to transform organic waste into two high-value outputs:** a stable organic amendment known as vermicompost, and a liquid byproduct often called vermileachate.

The process relies on surface-dwelling worms feeding on organic residues under aerobic, moist, and temperature-controlled conditions. Sources: (8), (12), (17)

OUTPUTS

Three main outputs: **vermicompost, vermileachate, and excess earthworms.**

Vermicompost is a stabilized organic amendment, rich in humus, beneficial microbes, and nutrients such as nitrogen (1–2%), phosphorus (0.6–1.5%), and potassium (0.4–0.6%). Vermileachate, a nutrient-rich liquid, can be used as a foliar spray or soil drench. Excess worms—resulting from healthy, reproducing colonies—can be harvested as a protein source for poultry or aquaculture, or reused as seed stock for new vermicomposting systems. All outputs hold value in regenerative agriculture and circular nutrient systems. Sources: (8), (12), (13), (17)

WASTE INPUT CONSIDERATIONS

All organic materials must be clean. While plant based is commonly used, animal manures such as cow dung are often added as starters. However, worms are sensitive to high concentrations of salt, oil, acidic foods (like pickles), and chemicals such as baking soda, vinegar, and lotions. At a small scale, suitable inputs include plant-based waste like vegetable peels and coffee grounds. For medium scale, waste is locally collected from markets, schools, and small institutions. At the industrial scale, feedstock mainly comes from agroindustrial byproducts like fruit waste, coffee husks, or manure, secured through contracts to ensure consistency and low contamination; mixed municipal waste should be avoided, though carefully sorted organic waste may be added in limited amounts.

COMMUNITY ENGAGEMENT

Worm composting is highly accesible and hands-on, promoting environmental education in schools and neighborhoods. It encourages behavioral change, and success depends on strong local leadership and social cohesion. Source separation is key in worm composting, promoting community awareness and participation. Sources: (19), (12)

Direct application as animal feed

DEFINITION

Involves the controlled use of **food waste**—such as surplus, unsold, or post-consumer food—**as livestock feed.**

This includes two main approaches: direct application, where food waste is sent from sources like hotels to farms for soil enrichment or animal feed, and processing, where meat and poultry waste is collected separately and treated in rendering plants under high temperature and pressure to produce safe animal feed or pet food components. Ruminants are typically excluded from meat-based scraps due to disease risk, and safe handling is essential to ensure animal health. Sources: (33), (34)

OUTPUTS

At **small and medium scale,** food waste is directly consumed by animals **without producing a distinct physical output—the benefit is embedded in the animal's growth or productivity.** In more **industrialized systems, food waste is converted into standardized feed ingredients.**

These may be dried, ground, or pelletized to ensure safety and extended shelf life. Nutritional profiles vary: processed coconut meal contains 25–30% crude protein, and apple waste offers 12% protein and 60% total digestible nutrients. Source: (33)

WASTE INPUT CONSIDERATIONS

At every scale, source separation is essential to ensure a clean, high-quality waste stream and prevent contamination. At a small scale, acceptable feedstock includes clean kitchen scraps (e.g., vegetables, bakery leftovers), which may require treatment if they contain animal products. At medium scale, the focus is on clean, segregated waste from food businesses and commercial establishments. At large scale, clean and uniform byproducts from agroindustries (such as food processors and slaughterhouses) are managed through long-term contracts, while post-consumer municipal waste is avoided due to high contamination levels.

COMMUNITY ENGAGEMENT

It engages communities through partnerships between local farmers, food providers, food markets, food waste generators (restaurants, school canteens), community gardens, etc. Its scale fosters on site management and educational activities like visits. It strengthens public awareness and builds lasting waste reduction habits. Sources: (4), (1)

Black Soldier Fly (BSF)

DEFINITION

Controlled use of the insect *Hermetia illucens* to convert organic waste into two valuable byproducts: protein-rich larvae and nutrient-rich frass.

The larvae can reduce the weight of organic waste by up to 80%, converting it into larval biomass (15-20% weight of the input waste) and into frass (another 30–40%), depending on substrate and system design. Sources: (4), (88).

OUTPUTS

Larvae-derived proteins and frass, with optional oil and chitin extraction. Dried larvae contain approximately 40–44% **protein** and 30–38% fat, making them a valuable ingredient in feed formulas for poultry, aquaculture, and pets. **The oil fraction**—rich in lauric, palmatin, oleic and linoleic acids, and other medium-chain fatty acids—can be extracted and used in feed formulations with positive effects on animal health (antimicrobial and immune system). The **frass**, a granular byproduct of the digestion process, functions as a nutrient-rich organic amendment, typically containing nitrogen, phosphorus, potassium, and organic matter, and contributes to improved soil health and microbial activity. The least explored but promising output of BSF technology is **chitosan**, which is a protein derived from chitin present in the larvae exoskeleton. This versatile biopolymer finds applications in biomedicine, antimicrobial agents, and cosmetics. Sources: (1), (5),(89),(90)

WASTE INPUT CONSIDERATIONS

Technically, BSF can be fed both organic materials and animal by-products, although the use of animal by-products is not permitted everywhere (see technical requirements). All organic materials should be clean, with a preference for waste coming from fruit, vegetables, and grains. At the small scale, kitchen waste is suitable. For medium scale, sources include markets, restaurants, and food processors, where sorting and a steady supply are essential. At the industrial scale, BSF systems can process municipal organic waste, market residues, and agro-processing byproducts, but require stable contracts, clear separation protocols, and coordinated logistics to ensure consistent, balanced and uncontaminated inputs. BSF could be bred in specialized facilities, and the young larvae distributed to waste generators for on-site waste treatment, minimizing transport of waste.

COMMUNITY ENGAGEMENT

It supports community-based initiatives by encouraging separate collection of organic waste, which is delivered to local BSF farmers to produce proteins and frass for local use. Revenue-sharing and reduced reliance on imported proteins and fertilizers strengthen these models. BSF can also be used directly at food waste generation sites, enabling local waste treatment and benefits for nearby communities. An example is at the compound of a university that operates a large canteen, allowing food waste to be treated locally while the frass can be used for local vegetable cultivation and larvae distributed to nearby communities for their chickens. Centralized breeding with local distribution of larvae offers further opportunities for community engagement and mutual benefit.

Anaerobic Digestion

DEFINITION

Anaerobic Digestion (AD) is a technology that treats organic waste —such as food scraps and sludge— where bacteria and several other microorganisms decompose organic materials in the absence of oxygen.

Sources: (46), (51)

OUTPUTS

Biogas: typically composed of 50–70% methane (CH_4), 30–40% carbon dioxide (CO_2), and trace gases such as hydrogen sulfide (H_2S) and ammonia (NH_3). After desulfurization and moisture removal, it can be used directly for heat, lighting, and power. When produced on a large scale, it can be upgraded to biomethane (containing over 95% CH_4) for grid injection into the gas grid or use as vehicle fuel. For vehicle applications, the biomethane must undergo additional purification and densification to meet fuel standards. **Digestate:** rich in nitrogen, phosphorus, potassium, and organic carbon—can be used as a liquid or solid fertilizer, enhancing soil fertility, microbial biomass, helps retain moisture, and nutrient cycling. Sources: (46), (51)

WASTE INPUT CONSIDERATIONS

All organic materials must be source-separated and free from chemicals and contaminants to ensure efficient processing and clear digestate fit for farming. At the small scale, suitable inputs include food scraps, organic waste including meat and fish from households and street markets, human toilets, and manure, with small amounts of fats and dairy tolerated. For medium scale, organics like fruit and vegetable waste or expired goods are used, emphasizing consistency and low contamination. At the large scale, biodigesters process organic waste from municipal programs, agro-industries, and food manufacturers, requiring strict screening and pretreatment to maintain system performance and safety. Anaerobic digestion is considered as a safe process where no pathogens can survive.

COMMUNITY ENGAGEMENT

Demonstrating tangible advantages—such as clean energy, fertilizer, and local economic opportunities—further motivates community involvement and helps ensure the long-term success of these projects. Sustained engagement depends on clear training, user-friendly design, maintenance, and technical support. Sources: (51), (52), (53)

BioCover

DEFINITION

Compost- or soil-based cover systems, known as biocovers, are engineered to enhance the microbial oxidation of methane emissions from landfills.

These passive systems are placed over aging or low-yield landfill cells as a replacement for conventional landfill gas collection. Biocovers provide a solution to reduce methane emissions from existing landfill waste, complementing broader waste diversion strategies. Typically, a biocover consists of a gas distribution layer and an overlying methane oxidation layer, usually made from mature compost, and also other locally sourced materials. Sources: (55), (56), (57), (58)

OUTPUTS

Methane oxidation and emission reduction.

As landfill gas diffuses through the biocover, methane (CH_4) is biologically oxidized by methanotrophic bacteria into carbon dioxide (CO_2), significantly reducing the overall greenhouse gas impact. Well-designed systems achieve CH_4 removal efficiencies between 70% and 100%. In addition, compost-based covers can sequester carbon and support aerobic microbial communities that stabilize nitrogen. Emissions of nitrous oxide (N_2O) are generally minimal—less than 2.3% of the CO_2-equivalent benefit—when mature, well-aerated compost is used. Sources: (56), (57), (58)

WASTE INPUT CONSIDERATIONS

Commonly compost or soil, both rich in microbial content, to enhance methane oxidation.

COMMUNITY ENGAGEMENT

Engagement is indirect but essential for building trust and raising awareness. Involving local stakeholders in siting and monitoring processes allows actors to actively participate in ensuring the proper operation of landfills. This not only improves public perception of landfill management but also strengthens support for climate action and landfill phase-out. Sources: (57), (58), (59)

Processing Time (shortest to longest)

	SMALL-SCALE	MEDIUM-SCALE	LARGE-SCALE
Animal Feed	**Immediate** use (daily if fresh and stored)	**24–48 hours;** Must be processed (e.g., cooked) to avoid spoilage	**24–48 hours** (dehydration/ sterilization); **3–10 days** (fermentation)
Black Soldier Fly	**10–15 days** (bioconversion); ~40 days (full cycle)* may differ depending on local conditions	**10–15 days** (bioconversion); **40–45 days** (full cycle)* may differ depending on local conditions.	**10–15 days** (bioconversion); 40–45 days (full cycle)* may differ depending on local conditions
Anaerobic Digestion	**15–30 days;** daily feeding is recommended	**20–30 days** hydraulic retention time; works best with daily or semi-continuous feeding	**20–40 days** with continuous or batch feeding to maintain output stability
Worm Composting	**45–60 days** (partial harvest after 3–4 weeks)	**30–60 days** (active) + **1–2 weeks** curing	**30–50 days** (active); **60–75 days** (total including curing)
Composting	**1–4 months** (active management); up to 24 weeks (passive systems)	**8–16 weeks** in total, including 2–4 weeks of active decomposition and a maturation phase	**10–16 weeks. 3–4 weeks active, 6-12 weeks** maturation
BioCover	Not applicable	Not applicable	**Operates passively/ continuously for years;** methane oxidation remains effective with proper compost conditions

Small-scale

Animal Feed	Some jurisdictions allow direct feeding without processing, but safe storage, exclusion of spoiled material, and hygiene must still be prioritized. Sources: (33), (36)
Composting	Often lightly regulated or unregulated, especially for on-site, non-commercial composting. Local rules may address zoning, odor control, pest management, and setbacks from neighbors or water sources. Community composting of multiple households might require registration or informing the neighborhood. Avoiding meat and dairy allows composting facilities to stay below permit thresholds and reduces regulatory burden. Documenting processes is advised to ensure transparency with neighbors. Sources: (22), (25), (31)
Worm Composting	Usually unregulated, especially if waste is generated and treated on-site. Local rules may address odor control, pest prevention, drainage, and restrictions on organic waste or composting in residential areas. Selling vermicompost or worms might trigger regulations related to organic amendments, fertilizers, or animal feed. Sources: (8), (13), (17)
Black Soldier Fly	Often unregulated or lightly regulated. Local rules may treat BSF rearing as livestock, waste handling, or agriculture. Backyard systems might face nuisance or health inspections for odor, flies, or neighbor proximity. Registration as a small waste generator or composting unit may be required. Selling larvae or frass occurs locally and may trigger labeling, safety, or feed regulations depending on the location. Sources: (1), (3), (4)
Anaerobic Digestion	Often lightly regulated or exempt from formal permits when used on-site and off-grid (e.g., household or farm units). Building and safety guidelines may apply due to gas storage and combustion risks (ventilation and H_2S removal). Nearby neighbors may trigger nuisance or odor regulations. Applying digestate to land must follow basic agricultural guidelines, especially for vegetables that are eaten raw. Selling biogas or digestate may require compliance with energy safety or fertilizer/soil amendments regulations. Sources: (46), (53)
BioCover	*Not applicable*

Medium-scale

Animal Feed

Operations must obtain permits to heat-treat animal-derived scraps and licenses to operate as feed suppliers. For example, U.S. law requires meat-containing scraps to be boiled at 100°C for 30 minutes in licensed facilities. State or local laws may impose stricter rules, including inspections and record-keeping. Compliance with both national and local authorities is necessary, especially for commercial or off-site sourced food waste. Sources: (33), (34)

Composting

Usually requires formal permits from local or regional authorities, including zoning clearance and permits for processing source-separated organics. Must demonstrate odor and leachate control, buffer zones, and detailed site plans covering drainage and erosion control. Compost must meet quality standards limiting pathogens, heavy metals, and inert materials. Regulations vary but often follow risk-based or best-practice and monitoring frameworks. Sources: (21), (31), (30)

Worm Composting

More likely to require municipal permits for waste handling, particularly if accepting inputs from external sources like markets or institutions. Health and environmental authorities may impose odor, leachate, and vector control measures. Selling vermicompost or vermileachate involves compliance with labeling and quality standards. Early coordination with regulators is recommended. Sources: (11), (12), (16), (17)

Black Soldier Fly

Require confirmation if insect bioconversion falls under waste, feed, or agricultural laws. Permits for waste handling, zoning, and environmental health are often needed. Commercial sales of larvae or frass must comply with animal feed and organic fertilizer standards. Overlapping rules from health, agriculture, and waste sectors may apply, so early coordination with authorities is advised. Sources: (1), (3), (4)

Anaerobic Digestion

Typically requires formal permits from municipal or environmental authorities, including operation permits, zoning approval, and possibly waste processing or energy licenses—especially if accepting food waste from third parties. ATEX (European certification for equipment safe to use in explosive atmospheres) zones get crucial relevance in this scale. Regulatory requirements often include operational training, environmental impact assessments, biogas management plans, odor and leachate control, digestate management, biogas flaring, and feedstock traceability. Sources: (46), (47), (51)

BioCover

Not applicable

Large-scale

Animal Feed

Food waste-to-feed operations require licenses for processing and heat treatment of animal-derived food scraps. Facilities must follow food safety rules, maintain traceability, proper labelling, especially regarding mammalian protein restrictions for ruminants. Additional regulations include environmental permits, waste handling standards, and separation from untreated waste. Overlapping waste and feed regulations can complicate compliance and increase costs, so harmonized licensing is important to avoid redundancy. Sources: (33), (34)

Composting

Subject to strict regulations due to scale and environmental impact. Permits include environmental approvals, solid waste treatment licenses, and zoning compliance. Requires comprehensive systems for leachate, odor and air pollution control, erosion prevention, and large buffer zones from residences and water bodies. Finished compost must meet strict safety standards. Input restrictions apply to hazardous or contaminated materials. Regulations are based on risk, no-net-degradation, or best-achievable standards depending on jurisdiction. Sources: (30), (31)

Worm Composting

Requires permits for waste processing, environmental protection, and public health. Obligations include leachate management, odor control, buffer zones, and environmental impact assessments. Commercial outputs must meet national standards for organic fertilizers. Large systems generally use controlled feedstocks (agroindustrial byproducts or manures) to ensure consistency and minimize contamination. Sources: (12), (14), (16)

Black Soldier Fly

Must fully comply with national laws, requiring multiple permits such as solid waste treatment, animal feed production, soil amendment standards, environmental impact assessments, occupational health, and zoning. Products (larvae, oil, frass) must meet quality standards for market entry. Regulations often involve several ministries (health, agriculture, environment, industry). Export operations must adhere to international standards (e.g., EU, Codex) for traceability and safety. Legal due diligence is essential. Sources: (2), (3), (5)

Anaerobic Digestion

Subject to comprehensive regulation with multiple permits for environmental impact, ATEX (European certification for equipment safe to use in explosive atmospheres) zones, energy generation, organic waste processing, and emissions control. Facilities must demonstrate control over methane emissions, odors, noise, and effluents, and maintain engineered systems for biogas capture, flare safety, and digestate storage. Digestate sale or land application requires meeting safety standards. Coordination across waste, energy, and agricultural regulations is needed to avoid overlap. Sources: (46), (47), (51)

BioCover

Biocovers typically require approval from environmental authorities, especially for landfill closure or methane mitigation, because these uses are closely tied to long-term environmental protection and regulatory compliance. As part of the landfill's final cover, biocovers must meet strict standards for emissions control and public health. Permits often require methane flux assessments, documented designs, long-term monitoring, and compliance with air quality and climate regulations. Compost used must meet safety standards, and authorities may also evaluate secondary emissions and require best available technology. Sources: (56), (57), (59), (91), (92)

Technical Requirements: **Infrastructure**

Small-scale

Animal Feed	Needs under $5m^2$ for collection, sorting, storage, and direct feeding. Food waste is manually sorted, with attention to moisture to avoid spoilage. Energy use is low, mostly refrigeration or simple drying. Transport is informal and relies on short supply chains near livestock to reduce spoilage and costs. Hygiene is maintained by pest exclusion and weather protection. Sources: (22), (24)
Composting	Uses simple bins (plastic, clay, wood) allowing airflow and drainage, or piles directly into the soil. Manual tools like forks or tumblers help control odor and pests. Energy use is minimal or negligible, with bins near kitchens or gardens for convenience. No transport is needed since composting is on-site. Key factors for efficient operations are source-separation, aeration, and moisture control. Requires up to 1–2 m^2 for a household, and proportionally bigger space for schools. Sources: (20), (21), (31)
Worm Composting	Constructed from local materials or commercial bins, requiring covers, drainage, and aeration. No machinery is needed; it requires only manual feeding and harvesting. Energy use is negligible. Worms need healthy initial seeding and protection from predators. Usually located near waste sources, thus transport is minimal. Suitable for backyards, patios, or indoors with up to 1–3 m^2 space. In colder climates, shelter or insulation are needed. Sources: (8), (13), (17), (18).
Black Soldier Fly	Minimal infrastructure is needed using local materials; shelter/heating must be considered. Home setups prioritize compact, low-maintenance designs. Access to starter larvae neonates ("seed") is essential; wild locally existing larvae may also be found in dumpsites and used to set up a new colony. Passive self-harvesting reduces labor. Space requirement is just a few square meters, making it suitable for backyards or small containers. On-site breeding is possible but often less controlled, thus ages of larvae differ and make it more difficult to reach high efficiency in bioconversion and survival rates. Small scale BSF farm uses locally sourced clean waste, with sufficient manual sorting and shredding. Sources: (1), (4), (6)
Anaerobic Digestion	Minimal infrastructure with prefabricated plastic or fiberglass digesters, or masonry fixed domes equipped with inlet/outlet valves, sealed biogas collection domes or bags, and simple piping to stoves, water heaters, or lamps is required. No electricity needed unless optional components are added, such as pumps, blowers, or grinders. Passive in warm climates; insulation or heating may be required in cold areas. Feedstock is treated on-site, eliminating transport needs. Manual feeding and basic water mixing will suffice. It is usually placed near kitchens or gardens, needing about 2-6 m^2 of space. Sources: (51), (53)
BioCover	*Not applicable*

Medium-scale

Animal Feed	Requires 100-300m² for receiving, pre-processing, storage, and cooking or dehydration. It uses advanced technologies like dehydration, pelleting, and extrusion to produce consistent, safe feed. Energy demand is high, especially for drying. Cold storage and refrigerated transport are key for longer supply chains. Feedstock is cleaner and more uniform, often from agro-industrial sources, supporting stable operations. Sources: (33), (44)
Composting	Uses windrows or aerated static piles, often with mechanized shredders, loaders, and turners. Moderate energy use is needed for aeration, leachate, and odor control. Waste is transported, sorted, and moisture-adjusted. It requires 500–1,500 m² including reception, active composting, and curing areas. In-vessel composting systems, in contrast, use enclosed reactors with automated control of aeration and temperature, requiring less space and allowing for more efficient process management. Sources: (30), (31), (33), (93)
Worm Composting	Structured layouts with zones for feeding, harvesting, and curing, often concrete or masonry beds. Pre-processing of waste (grinding, sorting) is necessary to remove unsuitable inputs like meat, dairy, or citrus. Some mechanization (sifters, shredders) may assist but core processes remain manual. Requires protection from weather and pests. Energy use is low, mainly for tools, water, and lighting. Typically needs 50–200 m² with roofed/shaded infrastructure. Transport of inputs and outputs may be required. Sources: (11), (12), (13), (16), (17), (18)
Black Soldier Fly	Requires structured infrastructure with separate logistics for larval rearing, prepupae separation, and residue handling. Waste must be pre-processed (sorting, shredding). Temperature, humidity, and light control are vital to run smoothly; climate control may be necessary. Starter colonies and colony maintenance protocols are crucial. Biosecurity, drainage, and leachate management are required. Moderate energy use scales with capacity. Site design must address odor and regulatory compliance. Space needed is about 100–300 m² for 0.5–3 tons/day throughput. Sources: (1), (2), (3)
Anaerobic Digestion	Requires structured infrastructure with zones for feedstock reception, sorting, homogenization (grinders, mixers), biodigestion, biogas use, and digestate storage. Digesters are fixed-dome, CSTR (Continuous Stirred Tank Reactor), covered lagoons or plug-flow, with pumps, valves, and heat/energy recovery units. Energy is needed for mixing, heating, and monitoring. Drainage, odor, and leachate control are essential. Proximity to feedstock sources reduces transport time. Requires 200–1,000 m² space to include storage, buffer zones, and equipment areas. Sources: (46), (47), (52)
BioCover	*Not applicable*

Large-scale

Animal Feed

Needs over 2,000 m^2 with covered reception, sorting, storage (dry and cold), and multiple processing steps including drying, pelleting, and fermenting. High energy inputs and strict hygiene controls are essential. Continuous supply of clean, homogeneous feedstock is critical. Efficient logistics with refrigerated transport can handle large volumes. Sources: (26), (33), (35)

Composting

Employs mechanized systems like windrows, aerated piles, or in-vessel composting with industrial equipment. In-vessel systems use more energy but offer better control. Facilities cover 2–5 hectares with reception, processing, leachate management, roads, and auxiliary services. Design accounts for transport logistics, traffic flow, and regulatory setbacks. Sources: (22), (31), (30)

Worm Composting

Industrial layouts with feedstock reception, pre-processing, composting beds or windrows, curing, and storage areas are needed. Inputs must be homogeneous and pre-treated; unsuitable materials must be excluded. Facilities are roofed/enclosed to regulate temperature, moisture, and leachate. Some mechanization supports operations, though decomposition is a biological process. Energy use is modest, and tied to equipment and water supply. Requires 4,000–8,000 m^2 operational space plus additional buffer and access areas of up to 10,000–15,000 m^2 in total. Transportation logistics for inputs and outputs are critical. Sources: (12), (14), (16), (17)

Black Soldier Fly

Industrial setups feature automated waste pre-processing, larval rearing, and separation. Climate control ensures productivity across multiple zones. Feedstock quality consistency is typically secured via contracts. Facilities are designed for continuous flow operations with leachate, odor control, biosecurity, and compliance. Dedicated breeding space with controlled photoperiods and skilled staff for colony genetics is required. Processing outputs according to the market needs is necessary - efficient drying and pulverising techniques, as well as packaging and logistics of distribution. Space requirement ranges from 2,500–5,000 m^2 net area, up to 6,000–15,000 m^2 to include access and buffer zones. Sources: (2), (3), (5)

Anaerobic Digestion

Requires industrial infrastructure with automated systems for feedstock sorting, grinding, slurry preparation, and continuous feeding. Large CSTR or modular plug-flow digesters integrate heating, agitation, and real-time monitoring. Facilities include biogas treatment (e.g., desulfurization), odor and leachate control, and energy recovery via CHP (combined heat and power) or upgrading units. Feedstock supply is secured through contracts. Must meet industrial safety and environmental standards. Requires 6,000–15,000 m^2 space for digesters, storage, traffic flow, and buffer areas. Sources: (46), (47), (49)

BioCover

Large-scale biocover systems need engineered landfill infrastructure with a gas distribution layer (e.g., gravel) beneath a compost or soil-based oxidation layer. Construction involves excavators and compactors to shape and layer the system. Though biocovers run passively without energy input, monitoring may use gas analyzers and flux chambers. Transport is limited to initial material delivery. Space requirements range from thousands to tens of thousands of square meters, covering full landfill cells or high-emission zones. Sources: (56), (57), (59)

Environmental Aspect: **Methane Reduction**

Animal Feed

Can significantly reduce environmental impacts associated with conventional feed production and waste disposal. Diverting food scraps from landfills lowers methane emissions, while displacing feed crops like corn and soy reduces demand for water, fertilizers, and land. Studies show it outperforms anaerobic digestion and composting in greenhouse gas reduction and energy efficiency. Environmental performance depends on logistics and processing methods. Sources: (31), (36), (44)

Composting

Reduces methane emissions by preventing anaerobic decomposition in landfills. An average of 78% of the methane emissions that would normally be released from landfills, representing a significant reduction in emissions from the waste sector. Compost also adds organic matter that improves soil's chemical, physical, and biological properties, reducing reliance on chemical fertilizers and supporting long-term soil health. When located near waste sources, composting further lowers emissions from transport, strengthening its environmental contribution. As a carbon-rich soil amendment, compost also enhances carbon sequestration by stimulating biological processes that store a portion of carbon in the soil and below-ground biomass, helping to mitigate climate change. Sources: (20), (22), (31), (61)

Worm Composting

Diverts organic waste from landfills and can reduce methane emissions by up to 50–60% compared to landfill disposal. While slower than thermophilic composting or BSF, the aerobic, low-temperature process avoids anaerobic decomposition, resulting in minimal direct greenhouse gas emissions. Additional benefits include improved soil carbon content when vermicompost is applied to land, reduced synthetic fertilizer use, and enhanced microbial biodiversity in treated soils. When implemented close to waste sources, further emissions reductions from transport can be achieved. Sources: (12), (14), (16)

Black Soldier Fly

Can reduce organic waste volumes by up to 80%, cutting methane emissions by 50–90% compared to composting or landfilling respectively. This reduction comes from the larvae's fast digestion of substrates, which prevents methane-generating anaerobic breakdown. A peer-reviewed study on livestock manure treatment found up to 87% reduction in methane emissions using BSF larvae. Locating facilities near waste sources also lowers emissions from transport. Additional benefits include reduced leachate, minimal land use, and nutrient recovery as animal feed and soil improver. Sources: (2), (3), (5), (7)

Anaerobic Digestion

Controlled anaerobic digestion in biogas plants or biodigesters optimizes the decomposition of food waste in closed environments, significantly reducing methane emissions, leachate, and odor that would otherwise result from uncontrolled landfill disposal. When biogas or biomethane displaces fossil fuels for cooking, heating, electricity generation, industrial energy needs or vehicle fuel, further emission reductions are achieved. Digestate application enhances soil fertility and reduces reliance on synthetic fertilizers, lowering indirect emissions from fertilizer production. Co-locating systems near waste generators and planning decentralized management to minimize transport-related emissions, supporting climate mitigation and local resource use. Sources: (46), (47), (51)

BioCover

Reduce landfill methane emissions by 60–100% through microbial oxidation, converting CH_4 into CO_2—a gas with far lower global warming potential. Unlike flaring, biocovers operate passively without combustion byproducts. Field studies show long-term performance without significant degradation, even in cold climates. When mature compost is used, nitrous oxide emissions remain negligible, ensuring high net climate benefit. Biocovers also avoid the infrastructure demands of gas extraction and energy systems, making them suitable for aging or remote sites. Applying biocovers on-site minimizes environmental disturbance and reduces emissions from material transport. Sources: (56), (57), (58), (59), (60)

Small-scale

Animal Feed	**Minimal investment;** as food scraps reduce feed and disposal costs, especially in rural or peri-urban areas with limited waste services. On-site use also promotes food sovereignty and enhances local resource efficiency. Source: (34)
Composting	**Low-cost** and decentralized, small-scale composting **saves on transport and disposal.** Built with local or commercial materials, it offers financial benefits mainly through avoided costs. Efficiency improves with household education and strong community participation. Sources: (22), (31)
Worm Composting	**Low-cost and accessible,** small-scale vermicomposting reduces household waste and landfill fees while producing compost for gardening. Initial worm stock (*Eisenia foetida*) can be costly and hard to source. Economically viable mainly through avoided costs and municipal support. Sources: (8), (13), (16), (18)
Black Soldier Fly	**Inexpensive and accessible,** small-scale BSF systems reduce municipal waste collection and transport needs. Key economic benefit lies in avoided costs, potentially justifying subsidies in high-organics areas. Sources: (1), (3), (4)
Anaerobic Digestion	Household or farm-scale biodigesters are **low-cost and reduce expenses on fuel and fertilizer.** They also lower municipal waste collection needs, especially in rural areas. Cost savings can justify support through energy, sanitation, or climate programs. Sources: (51), (53)
BioCover	*Not applicable*

Medium-scale

Animal Feed

Cuts transport, disposal, and feed costs. However, if treatment is needed (e.g., dehydration), costs may double compared to other methods. **Success depends on logistics,** proximity to farms, and clean feedstock. Sources: (3), (8)

Composting

Offers savings on landfill transport and tipping fees. Cost-effective for municipalities, though compost sales rarely cover costs. Financial success depends on clean input, nearby users, early farmer involvement, and clear market planning. Public-private or municipal models are feasible. Sources: (21), (22), (31)

Worm Composting

Offers savings on landfill transport and tipping fees. Supports local waste solutions but offers limited profits. Compost has low market value; vermileachate may generate some revenue if properly treated and marketed. Viability depends on low costs, steady feedstock, and institutional backing. Sources: (11), (12), (13), (16)

Black Soldier Fly

Offers municipalities savings on landfill transport and tipping, with revenue from larvae, frass, and oil. Financial viability depends on stable feedstock, clear output markets, and strong management. Cooperative or public-private models are often used. Sources: (2), (3), (4)

Anaerobic Digestion

Requires **moderate investment** but offers returns via reduced disposal costs, energy production, and fertilizer substitution. Revenue may come from tipping fees or feedstock contracts. Viability improves with stable inputs and access to climate or energy subsidies. Sources: (47), (51), (52), (54)

BioCover

Not applicable

Economical Aspects: **Financial Rationale**

Large-scale

Animal Feed

Economically viable with efficient processing and secure markets. Despite higher upfront costs, savings from feed production, reduced tipping fees, and potential revenue can balance investments. Profitability depends on hygiene, input reliability, and market stability. Sources: (34), (36)

Composting

Requires **major investment in infrastructure and labor.** Viability depends on tipping fees and clean, source-separated waste. **Compost sales alone are insufficient;** it is essential to develop local markets and secure customers early on, as producing a product you cannot sell undermines the entire effort. Sources: (22), (31)

Worm Composting

High infrastructure and labor costs. Compost and leachate rarely cover expenses. Profitability is limited without policy incentives or circular economy models. Better suited for public or subsidized operations. Sources: (12), (14), (16)

Black Soldier Fly

High investment but provides multiple revenue streams from larvae, soil improver, and oil. Cost-effective for carbon mitigation and landfill diversion. Success relies on long-term contracts, diversified feedstock, and quality control in public-private or private models. Sources: (2), (3), (5)

Anaerobic Digestion

High upfront costs but benefits from economies of scale. Profits come from energy sales, tipping fees, and digestate. Financial success depends on feedstock consistency, market value of outputs, and access to subsidies. Source: (49)

BioCover

Affordable methane mitigation option for legacy landfills. It doesn't produce revenue but can reduce emissions liabilities and policy incentives. Key costs include site assessments, compost transport, and installation. Local compost sourcing keeps costs low; distant hauling raises them. Monitoring adds upfront costs, but long-term operations are passive and low-maintenance. Compost typically lasts 5–7 years, offering favorable life-cycle economics. Sources: (56), (57), (58), (59)

Economical Aspects: **Scalability**

Animal Feed

Influenced by supply chain logistics, technology, and market demand. When feedstocks are consistent and pre-treated (e.g., heat-dried), systems can be expanded with minimal additional infrastructure beyond drying, grinding, or pelletting. Industrial operations benefit from integrating food waste into existing feed manufacturing lines, reducing reliance on land and water compared to commodity feed crops. However, contamination, variability in waste composition, and regulatory constraints remain barriers to wider adoption. Policy support, public-private partnerships, and standardized safety protocols are critical to ensure safe and cost-effective expansion. Sources: (34), (36)

Composting

Highly scalable, ranging from household bins to large industrial systems. Expansion is simple: increase the composting area, input volume, or the number of processing units. It does not require specialized organisms—microbes are naturally present and self-sustaining, reducing technical barriers. For industrial systems, or regions with prolonged rainy seasons, scalability may depend on access to roofed or protected areas, or investment in impermeable covers. Windrow and in-vessel systems can scale with equipment and space. Across all scales, success depends on steady feedstock supply, site layout, and early planning for output distribution. Sources: (24), (30)

Worm Composting

Scalable across small- to medium-operations but presents limitations at industrial scale. Its low-tech nature makes it accessible to households, schools, and cooperatives, and it can be expanded modularly. However, as scale increases, so do challenges in labor, land requirements, climate control, and feedstock consistency. Unlike BSF, which is fast and compact, vermicomposting is slower, less space-efficient, and harder to automate. Its primary output—compost—has limited market value unless part of a certified or branded system. Despite these constraints, vermicomposting remains a strong option for community-scale circular models, especially where social, agricultural, or educational outcomes are prioritized over rapid throughput or profit. Sources: (12), (13), (14)

Black Soldier Fly

Inherently scalable, functioning effectively at household, mid-sized, and industrial levels. It does not require complex infrastructure, making it adaptable to a range of contexts and geographies. Ongoing improvements in system design and genetics are expected to reduce costs and improve yields. The byproducts—protein-rich larvae and nutrient-dense frass—are already valuable in feed and agriculture markets, with potential for higher margins as circular bioeconomy policies expand. However, BSF will face increasing competition from precision fermentation and other next-generation protein sources. Long-term viability will depend on positioning not only as a protein solution but as a cost-effective, decentralized waste management strategy. Sources: (2), (3), (5)

Anaerobic Digestion

Anaerobic digestion is **highly scalable and adaptable**, producing renewable energy and nutrient-rich digestate. However, digestate often requires further composting to ensure safety and value, as it can contain contaminants like PFAS (Per- and polyfluoroalkyl substances). While promoted for circular economy goals, biogas systems face economic and technical barriers, and may unintentionally support intensive farming practices. Environmental justice principles call for careful oversight to prevent pollution and ensure benefits reach all communities, not just large industrial operators. Sources: (46), (47), (51)

BioCover

Inherently scalable and adaptable to diverse landfill contexts. It can be deployed over entire landfill surfaces or targeted high-emission zones, making them suitable for both small and large sites. Because they rely on passive microbial oxidation and locally sourced compost, implementation is feasible without major infrastructure. Scalability is limited more by material availability and site-specific methane distribution than by technical complexity. Biocovers are particularly suited for aging or closed landfills. Their modular nature and low energy demand support phased deployment and integration into post-closure care strategies. Sources: (56), (57), (59)

Social Aspect: **Job Creation Potential**

Animal Feed

ENTRY BARRIERS

Low to moderate

CAPACITY SKILLS NEEDED

Personnel must understand regulatory restrictions and ensure exclusion of unsafe materials. In industrial settings, coordination between nutritionists, feed technologists, and operators is essential to maintain feed consistency, optimize energy use, and safely incorporate alternative ingredients. Operators must be familiar with computerized systems, Good Manufacturing Practices (GMP), and Hazard Analysis and Critical Control Points (HACCP). Ongoing training and communication enhance process control and product quality. Source: (44)

JOB CREATION POTENTIAL

Generates jobs in collection, transport, and processing, especially in informal or decentralized settings. Models like Rutgers University's show how local partnerships with farmers create stable employment and business opportunities. Sources: (33), (44)

Composting

ENTRY BARRIERS

Low

CAPACITY SKILLS NEEDED

Operating composting systems requires different levels of trained personnel (from basic to more specialized) to manage picking of contaminated materials, moisture balance, aeration, and temperature control. Staff must understand how to operate shredders, turn equipment, and monitor compost maturity. At all scales, knowledge of acceptable feedstock and contamination risks is essential. Municipal staff or community members may need initial training and ongoing support to maintain quality standards and avoid odor, pests, or anaerobic conditions. Sources: (31), (30)

JOB CREATION POTENTIAL

Labor-intensive, creating jobs in collection, sorting, processing, and marketing. Small-scale composting can employ significantly more workers per tonne than landfilling or incineration, supporting local economies and small businesses. These include low-qualification jobs that offer more opportunities for waste pickers inclusion. The use of composting to manage organic waste generates an average of 6.6 jobs/10,000 tonnes per year (TPY). Sources: (24), (25), (86)

Social Aspect: **Job Creation Potential**

Worm Composting

ENTRY BARRIERS

Low

CAPACITY SKILLS NEEDED

Requires basic technical knowledge but consistent attention. Operators must understand worm biology, feeding rates, moisture, temperature, and pH control. Worms are more sensitive than compost microbes and may require closer monitoring—especially under fluctuating conditions. At a small scale, informal training or guides are often sufficient. Medium and large systems demand more structured skills in feedstock management, environmental control, and product quality. Practical experience in composting or horticulture is helpful. Municipal or non-government organization (NGO)-supported training may be necessary to build capacity in community or cooperative settings. Sources: (8), (12), (13), (16)

JOB CREATION POTENTIAL

Fosters inclusive, community-level job creation through schools, cooperatives, and neighborhoods. Encourages environmental education and shared ownership of waste solutions, though success depends on ongoing engagement and training. Sources: (12), (19)

Black Soldier Fly

ENTRY BARRIERS

Low to moderate

CAPACITY SKILLS NEEDED

Basic training is needed for usual operations. Users need to understand the BSF life cycle, feeding requirements, and basic hygiene practices. Most systems can operate without technical expertise, especially if starter larvae are sourced externally and breeding is outsourced to specialised facilities. Community workshops or visual guides can support adoption. Common challenges include poor waste selection, under- or overfeeding, and neglecting moisture or airflow—simple troubleshooting capacity is key. Marketing and distribution channels of the outputs is essential to ensure financial flow. There exist multiple open source guides and an interactive Community of Practice to exchange between peers. Sources: (1), (4), (6)

JOB CREATION POTENTIAL

Creates employment at all scales—from home-based care to roles in sorting, larval rearing, feeding, transport, and product marketing. Offers a pathway to formalize jobs in organic waste management, particularly in urban and peri-urban areas. With better access to quality animal feed and soil improvers, farmers will yield better outputs thus potentially increasing jobs in rural areas. Sources: (2), (4), (6)

Social Aspect: **Job Creation Potential**

Anaerobic Digestion

ENTRY BARRIERS

Moderate

CAPACITY SKILLS NEEDED

Operating anaerobic digestion systems requires personnel trained in feedstock preparation, digester loading, biogas safety, and basic microbiological principles. Staff must understand factors affecting methane yield—such as antibiotics presence in animal manure for instance, substrate mix, pH, temperature, and retention time—and be able to identify and respond to signs of process imbalance. Equipment operation includes handling pumps, biogas systems, safety valves, and safety and monitoring instruments. At larger scales, staff must also manage digestate handling, emissions monitoring, and compliance documentation. Training is critical across all levels to avoid system failure, ensure safety, and maintain biogas quality. Municipal operators and community members may require capacity-building support for long-term reliability and regulatory compliance. Sources: (46), (47), (51)

JOB CREATION POTENTIAL

Generates jobs from small-scale system maintenance to skilled work in plant operation and gas upgrading. Supports formal employment in organic waste management while promoting local energy access and circular economy practices. Sources: (46), (51), (52)

BioCover

ENTRY BARRIERS

High

CAPACITY SKILLS NEEDED

Implementing and maintaining large-scale biocover systems requires multidisciplinary expertise. Personnel must understand landfill gas behavior, methane oxidation processes, and compost dynamics. Skills in site surveying, gas flux measurement, and material selection are essential for proper system design and installation. Field technicians must monitor gas concentrations, surface emissions, and compost temperature and moisture. Long-term success depends on the ability to interpret monitoring data and adjust system conditions accordingly. Laboratory capacity for oxidation potential testing and emissions analysis may also be required to support regulatory reporting and performance verification. Sources: (56), (57), (59)

JOB CREATION POTENTIAL

Creates specialized roles in engineering, landfill management, and emissions monitoring. While less labor-intensive, it supports skilled employment in methane mitigation and builds local capacity in environmental services. Sources: (56), (57), (59)

Challenges & Opportunities

Animal Feed

CHALLENGES

Strong regulatory and safety challenges. It is often illegal to feed untreated food waste, especially with animal products, due to risks like foot-and-mouth disease or bovine spongiform encephalopathy. Although heat treatment (e.g., boiling 30 minutes at 100°C) makes waste microbiologically safe, concerns about non-compliance remain. The European Union encourages animal feed use but enforces strict biosafety standards that severely restrict applications. Consistent waste separation and freshness are crucial for safety. Sources: (33), (34), (35), (37)

OPPORTUNITIES

Reduces reliance on commodity crops like soy and corn, lessening land use, water demand, and deforestation. Species-specific approaches can optimize nutrition and safety. Success depends on investment in segregation systems and public-private partnerships to scale hygienic, regulated processing. Countries like Japan and South Korea recycle over 35% of food waste this way, using strict regulation and thermal treatment. Sources: (32), (34), (40), (42)

Composting

CHALLENGES

A key barrier is the lengthy and inconsistent permitting and zoning process. Properties must provide adequate space and buffers, increasing complexity. The compost market is underdeveloped: low and unstable demand discourages investment. Post-consumer waste contamination by plastics and glass raises processing costs and reduces quality, therefore, separation at source is essential for quality. The absence of standardized national compost specifications in some countries further weakens buyer confidence. Coordinated policy, education, and supply chain management are needed. Sources: (32), (26)

OPPORTUNITIES

Composting saves landfill space and produces valuable soil amendments that improve soil health, water retention, and crop yields. Emerging policies—state compost procurement laws, incentives, —are expanding markets and financial viability, especially in underserved areas. Composting supports regenerative agriculture, job creation, and climate mitigation through carbon sequestration. Promoting compost in infrastructure, landscaping, and agriculture can embed it in circular economy initiatives. Composting can be added as a new waste stream service to the separate collection and processing of materials done by waste picker organizations, leveraging their work. Sources: (32), (25)

Challenges & Opportunities

Worm Composting

CHALLENGES

Operational and biological limits include worm sensitivity to moisture, temperature, and pH, requiring stable environments that can be hard to maintain outdoors or in variable climates. High-moisture inputs must be carefully managed to avoid overheating or anaerobic conditions. Vermicomposting cannot directly process meat, dairy, or oily waste, often needing pre-composting steps that add cost. Throughput is slow as worms and microbes gradually stabilize waste under mesophilic conditions, requiring space, time, and careful feeding. Maintaining hygienization is challenging due to low process temperatures. An emerging risk is invasive worm species (e.g., *Amynthas*), which can disrupt ecosystems. Success depends on trained operators, infrastructure, and long-term oversight. Sources: (12), (13), (14), (18)

OPPORTUNITIES

Suited for decentralized, local organic waste management, especially in urban areas. It reduces transport needs and yields high-quality soil amendments that enhance nutrient availability, soil structure, and microbiology—key for resilient food systems. Worms themselves are valuable products for animal feed or aquaculture. Market prices vary, with potential in premium channels. Scaling requires supportive policies, guaranteed feedstock, and demand development. Source: (12)

Black Soldier Fly

CHALLENGES

Regulatory uncertainty is widespread, especially where insect waste treatment overlaps health, agriculture, and environment sectors. Misconceptions about hygiene, waste, and pests cause resistance among authorities and communities. A stable, uncontaminated feedstock supply is essential; contamination or volume fluctuations reduce productivity. Market access for larvae, frass, or oil is limited by emerging standards and buyer skepticism. Competition from alternative protein technologies (e.g., precision fermentation) may pressure BSF to better differentiate itself. Sources: (3), (4), (5)

OPPORTUNITIES

Offers scalable, circular, low-carbon waste treatment adaptable to various sizes. It meets demand for sustainable local protein, organic soil improver, and landfill diversion, supporting compliance with organic waste bans and emissions targets. Co-locating BSF with markets or agro-industries improves efficiency. Opportunities exist for carbon finance, green jobs, and enhancing regional food system resilience. Sources: (2), (3), (5)

Challenges & Opportunities

Anaerobic Digestion

CHALLENGES

Regulatory and permitting complexity delays projects, especially medium and large scale, due to overlapping rules for waste, energy, and agriculture. Siting near waste sources is limited by land availability, zoning conflicts, and community concerns about odor, safety, and traffic. Feedstock variability and contamination (especially post-consumer food waste) disrupt digestion and increase preprocessing costs. Inconsistent digestate quality and unclear fertilizer standards hamper market development. Financial viability relies on long-term feedstock contracts, energy pricing, and sustained policy support, which vary greatly by region. Sources: (46), (47), (49), (54)

OPPORTUNITIES

Reduces landfill use while generating renewable energy and nutrient-rich digestate to replace chemical fertilizers. It supports climate goals by capturing methane and displacing fossil fuels. Policies like organic waste diversion mandates and feed-in tariffs boost financial viability and investment. Biogas promotes local jobs, rural energy resilience, and circular economy integration via closed-loop nutrient and waste management. Sources: (46), (47), (49), (51)

BioCover

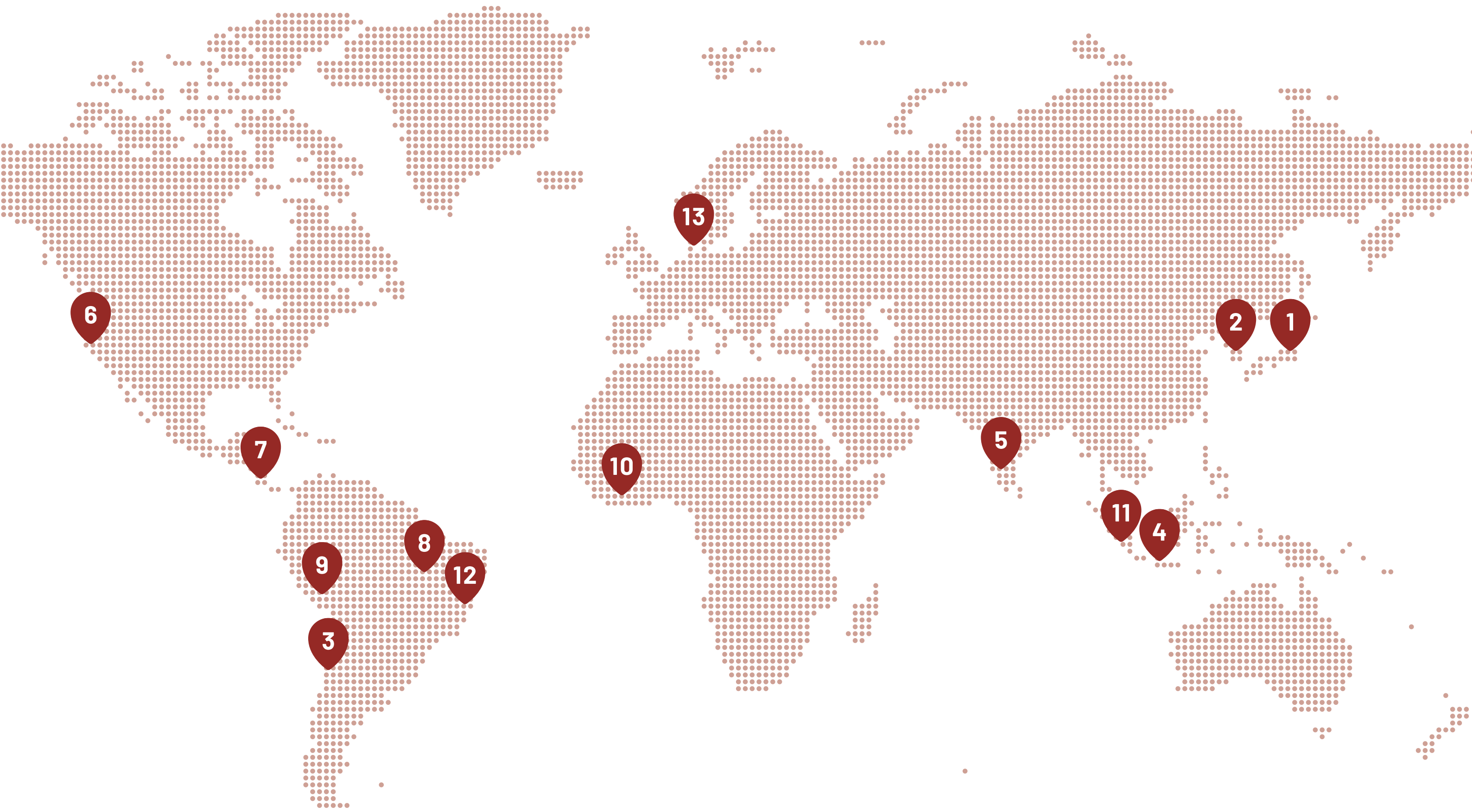
CHALLENGES

Scaling faces structural and operational barriers. Regulatory uncertainty arises because biocovers fall between waste management and air quality jurisdictions, complicating permits and accountability. The technology is underused due to limited awareness among landfill operators and decision-makers. Sourcing and transporting large amounts of mature compost can be expensive where local supply is low. Compost degrades over 5–7 years, requiring periodic replacement; performance varies with moisture, compaction, and landfill gas flow. Lack of standardized monitoring protocols and long-term funding mechanisms constrain adoption. Sources: (56), (57), (58), (59)

OPPORTUNITIES

Provide a low-cost, low-maintenance methane mitigation option for legacy landfills, making them specially suitable for meeting global climate targets. Their passive operation not only fits areas lacking active gas collection infrastructure but can also serve as a more effective and practical substitute. Expanding methane reduction targets may enable climate finance opportunities. Biocovers promote reuse of local compost, improve landfill post-closure care, and support site rehabilitation. With standardized protocols and policy recognition, biocovers could become mainstream climate tools in waste management. Sources: (56), (57), (58), (59)

Success Stories



Animal Feed

1 2

Japan and **South Korea** recycle

36–43%

of food waste as animal feed under tightly regulated systems.

3

Fundación Realim in **Chile** operates a food waste-to-feed circular model that integrates social and environmental goals through local collection and delivery systems.

Sources: (34), (36)

Composting

4

In **Surabaya, Indonesia,** the city implemented a decentralized composting strategy by distributing 19,000 composting bins to households and empowering community leaders and women's groups to promote source separation. The program successfully diverted up to 40 tonnes of waste per day and accounted for only 1–2% of the city's waste management budget.

5

Hasiru Dala is a **Bengaluru**-based organization that supports over 30 Dry Waste Collection Centers in India through decentralized composting projects that process organic waste from communities and markets. Their work has helped more than 8,500 waste pickers gain formal recognition and access to social services.

6

San Francisco's compost system, launched citywide in 1996, uses a mandatory green bin for all food scraps, yard trimmings, and soiled paper from homes and businesses. Over 500 tonnes of organic waste are collected daily and processed by Recology into compost for local farms and vineyards. This program is a key reason the city diverts over 80% of its waste and avoids about 90,000 metric tonnes of CO_2e annually—equal to removing 20,000 cars from the road.

Sources: (31), (20)

Worm Composting

7

In **Costa Rica**, the company Lombrictica has been producing and selling vermicompost since 2002. It supplies the agricultural sector with standardized organic amendments and has established a retail presence in the country. This model showcases how small-to-medium enterprises can build markets for vermicompost through product consistency, branding, and outreach.

Sources: (11), (9), (15), (94)

8

In **Brazil**, the R4 Project (Rancho Reduz, Recicla e Recomeça) in Rancho Queimado, Santa Catarina, launched in 2018, distributed home composters to residents to promote decentralized composting and reduce landfill waste. Serving a population of 3,411, the project recycles 30 tonnes of organic waste annually—cutting organic landfill disposal by 25%—and achieves a 40% dry waste recycling rate. The initiative has reduced emissions by 20 tonnes CO_2eq and 0.64 tonnes CH_4 per year, saved USD40 per tonne composted, and led to a 70% drop in recyclable materials sent to landfill, with a total investment of around USD 99,000 between 2018 and 2022.

Black Soldier Fly

9

In 2023, the Climate and Clean Air Coalition (CCAC) studied a Black Soldier Fly (BSF) facility for **Lima, Peru,** where over 8,600 tonnes of municipal waste are generated daily, more than half of which are organic. The proposed plant would process 250 tonnes/day, mainly from food markets. The study found BSF technically and legally feasible in Lima, with potential to cut methane emissions by over 50% versus traditional methods. Key factors for success include co-location with markets, stable tipping fees, and strong downstream markets. Economic viability is likely above 100 tonnes/day. The Ministry of Environment recognized BSF as a priority circular economy technology, especially for Amazonian regions with organic inputs and aquaculture needs.

10

At small scale, **NGO Living Soils in Grand Bassam**, Cote d'Ivoire, created a successful low tech decentralised "outgrowers" model where the breeding stage is managed at the Farm Centre Abel, while the neonates are distributed to five locations where waste is generated. Local markets collect their organic waste to be sent to the fattening locations. The farm started operating in January 2025 and currently results in monthly diversion of 30 tonnes of organic waste from landfills (63 tonnes of CO2-eq avoidance), producing 3 tonnes of larvae, while directly employing 8 workers.

11

In **Neglasari, Bandung in Indonesia,** the waste management system is a collaborative effort: YPBB established the separated collection system, while the BSF and composting infrastructure was developed by the city government authorities. Although overall waste reduction remains limited due to compliance issues on source separation, the project has successfully processed between 500 and 700 kg of organic waste daily—about 40% to 60% of the area's estimated 1,200 kg organic waste potential. Strong leadership from the Village Head has been crucial, particularly in budgeting, labor provision, and requiring local administrators to practice home composting, setting an example for residents.

Source: (3)

Anaerobic Digestion

12

The Caju Ecopark in Rio de Janeiro, **Brazil,** is piloting a circular economy model for organic waste management. In 2024, its "Biomethanization Unit" processed 4,300 tonnes of organic waste from schools, restaurants, supermarkets, and tree pruning, converting it into renewable electricity and biogas, which powers the Ecopark's operations and electric vehicles for its Food Bank. The Food Bank, launched in 2024, supports over 700 vulnerable residents in the Caju neighborhood, with more than 16 tonnes of food donated by local supermarkets. Additionally, the Ecopark produced over 540 tonnes of organic compost ("Fertilurb") in 2024, used in urban agriculture and reforestation programs throughout Rio de Janeiro.

Source: (55)

BioCover

13

A full-scale biocover system was implemented at the Klintholm landfill in **Denmark** in 2009 over a 4,800 m^2 area using locally sourced compost and crushed concrete. Designed to mitigate methane emissions from a closed cell with no gas recovery infrastructure, the biocover achieved 80% average methane oxidation efficiency. Six years later, despite no maintenance, field measurements confirmed sustained performance, even during winter. Elevated compost temperatures (13–27°C) and consistent gas oxidation rates demonstrated the system's resilience and long-term functionality in temperate climates.

Source: (59)

Conclusions and Recommendations

Policymakers play a pivotal role in transforming organic waste from a challenge into a valuable community resource. The following key takeaways highlight proven strategies and actionable insights that can help cities design effective and inclusive organic waste management systems, driving environmental, social, and economic benefits for their communities.

1 Organic waste is a resource rich in nutrients and energy that, when managed properly, can support local agriculture, energy generation, job creation, and methane mitigation.

The true value of organic waste management strategies lies in their long-term benefits—protecting the environment, improving public health, and delivering lasting community savings. While life cycle costs may exceed the direct market value of outputs, these systems reduce landfill use, cut methane emissions, and close nutrient cycles. By treating organic waste as a valuable asset and designing systems that maximize these broader benefits, municipalities can build healthier, more resilient communities.

2 A waste management hierarchy should guide action.

Prevention comes first—often through policies beyond the waste sector—followed by redirecting organic waste to secondary markets or animal feed where feasible, and otherwise returning it to soils via composting, or using it for energy through anaerobic digestion. Landfilling organic waste, due to high methane emissions and nutrient loss, should be avoided. Robust guidance and trained inspectors are key to reducing regulatory uncertainty and enabling safe food waste donation and recovery for both human and animal consumption.

3 Effective organic waste management starts with strong source separation, supported by regular, intuitive collection systems, and active community engagement.

When residents, local groups, and waste pickers are involved in sorting organics at the source, municipalities can leverage a wide range of scalable technologies—such as Black Soldier Fly processing, vermicomposting, composting, anaerobic digestion, and landfill biocovers—tailored to their unique needs. By integrating public participation with the right technical solutions, communities can transform organic waste from a challenge into a valuable resource, building more efficient, inclusive, and sustainable management systems.

4 While technological solutions for organic waste management are well established, the real opportunity lies in optimizing logistics.

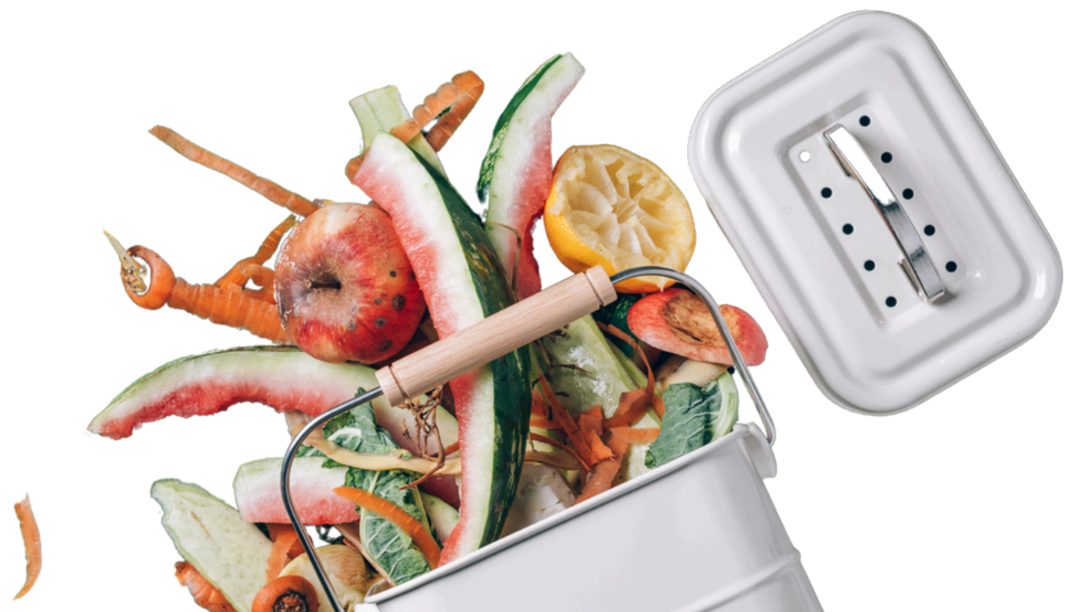
By treating food waste as close to the source as possible, municipalities can reduce transportation costs and minimize contamination from packaging and plastics. Designing systems that leverage spatial and material efficiencies—such as decentralized collection and processing—allows communities to turn logistical challenges into advantages, creating cleaner, more cost-effective waste streams that are easier to process and recycle.

5 Strategy selection must be context-driven.

If a decentralized option reduces transport costs and performs better financially—without creating greater environmental or social harms—it should be prioritized. Factors such as availability of space, waste volume, geographic dispersion, regulatory capacity, and methane mitigation potential should guide decisions. For example, processing organic waste that is 30k away from their point of generation may be inefficient; in such cases, smaller-scale composting or BSF systems located close to the source may yield better outcomes.

6 A major advantage of today's organic waste management technologies is their flexibility and inclusive potential to create jobs with low entry barriers.

Decentralized options like Black Soldier Fly processing, composting, and vermicomposting are accessible to small businesses, cooperatives, and individuals—including waste pickers—enabling their inclusion and formalization within the sector. These systems not only generate employment but also empower community groups and the informal workforce to participate in and benefit from new value chains.



Bibliography

Black soldier fly

1. *Amrul, N. F., Ahmad, I. K., Ahmad Basri, N. E., Suja, F., Abdul Jalil, N. A., & Azman, N. A. (2022). A review of organic waste treatment using Black Soldier Fly (Hermetia illucens). Sustainability, 14(8), 4565. https://doi.org/10.3390/su14084565*
2. *Bruno, D., Orlando, M., Testa, E., Carnevale Miino, M., Pesaro, G., Miceli, M., ... & Tettamanti, G. (2025). Valorization of organic waste through black soldier fly: On the way to a real circular bioeconomy process. Waste Management, 191, 123–134. https://doi.org/10.1016/j.wasman.2024.10.030*
3. *Climate and Clean Air Coalition (CCAC). (2024). Case study: Linking waste management and protein production through insect technology. https://www.ccacoalition.org/news/ccac-case-study-linking-waste-management-and-protein-production-through-insect-technology*
4. *Diener, S. (2010). Valorisation of organic solid waste using the Black Soldier Fly, Hermetia illucens, in low and middle-income countries [Doctoral dissertation, ETH Zurich]. https://www.research-collection.ethz.ch/handle/20.500.11850/152792*
5. *Tepper, K., Edwards, O., Sunna, A., Paulsen, I. T., & Maselko, M. (2024). Diverting organic waste from landfills via insect biomanufacturing using engineered black soldier flies (Hermetia illucens). Communications Biology, 7, 862. https://doi.org/10.1038/s42003-024-06516-8*
6. *Black Soldier Fly Technology Flier. (2024). BSF infographic: Using nature to valorize organic waste and create circular economy emissions mitigation. Internal publication (no formal author listed).*
7. *Sanchez Matos, J., de Aráujo, L. P., Allaman, I. B., Lôbo, I. P., de Oliva, S. T., Tavares, T. M., & de Almeida Neto, J. A. (2021). Evaluation of the reduction of methane emission in swine and bovine manure treated with black soldier fly larvae (Hermetia illucens L.). Environmental Monitoring and Assessment, 193, Article 460. https://link.springer.com/article/10.1007/s10661-021-09252-2*

Worm composting

8. *Somarriba Reyes, R. J., & Guzmán Guillén, F. (2004). Guía de Lombricultura. Universidad Nacional Agraria, Dirección de Investigación, Extensión y Posgrado (DIEP). Serie Técnica No. 4.*
9. *Cambronero, N. (2008). Crece la demanda de fertilizantes orgánicos. La República. https://www.larepublica.net/noticia/crece-demanda-de-fertilizantes-organicos*
10. *Duc asse, V., Capowiez, Y., & Peigné, J. (2022). Effect on earthworm's communities of different organic fraction of municipal solid waste treatments applied on field [Poster]. INRAE & Institut Supérieur d'Agriculture Rhône-Alpes. https://doi.org/10.13140/RG.2.2.16858.93123*
11. *Deshpande, A. (2011). Municipal solid waste management (composting and vermicomposting) project. https://doi.org/10.5281/zenodo.8357044*
12. *Ducasse, V., Capowiez, Y., & Peigné, J. (2022). Vermicomposting of municipal solid waste as a possible lever for the development of sustainable agriculture: A review. Agronomy for Sustainable Development, 42(5), 1–40. https://doi.org/10.1007/s13593-022-00819-y*
13. *Churchill, S. (2020). Complete guide to continuous flow vermicomposting. Urban Worm Company. https://urbanwormcompany.com/complete-guide-to-continuous-flow-vermicomposting/*
14. *Solanki, S., & Mahore, G. (2021). Low-cost large-scale vermicompost unit. Journal of Physics: Conference Series, 2115(1), 012026. https://doi.org/10.1088/1742-6596/2115/1/012026*
15. *Maddock, N. (n.d.). NutriSoil Case Study: Col Harper – Empowering Farmers, Enriching Food. NutriSoil. https://nutrisoil.com.au*
16. *Rodríguez Pérez, L. A., Borroto Pérez, M., Vega Guillén, O., Morales Rojas, M., & Gutiérrez Rojas, I. (2019). Programa de lombricultura para el manejo de residuos comunitarios. M+A Revista Electrónic@ de Medio Ambiente, 20(1), 120–141.*

17. Ontario Ministry of Agriculture, Food and Rural Affairs. (2010). Vermicasting (or vermicomposting). https://www.ontario.ca/page/vermicasting-or-vermicomposting
18. Uncle Jim's Worm Farm. (2020). Vermicomposting for beginners. https://unclejimswormfarm.com/vermicomposting-for-beginners/
19. Elizondo Coto, F. (2004). La lombricultura como modelo alternativo para el manejo de desechos sólidos orgánicos de una comunidad urbana en San Sebastián, San José [Reporte final, Instituto Tecnológico de Costa Rica].

Composting

20. Composting 101. (2020). Natural Resources Defense Council (NRDC). https://www.nrdc.org/stories/composting-101
21. Saypariya, D. C., & al. (2024). Composting of organic fraction of municipal solid waste in a three-stage biodegradable composter. Heliyon, 10, e37444. https://doi.org/10.1016/j.heliyon.2024.e37444
22. Department of the Environment, Tourism, Science and Innovation (DETSI), Queensland. (2023). How to compost effectively: Step-by-step guide.
23. Tamás, A., et al. (2019). STEPS in organic fraction of municipal solid waste – Composting and compost quality evaluation. Scientific Papers. Series A. Agronomy, LXII(2), 144–146.
24. H2020 Project. (n.d.). Valorise the organic fraction of municipal solid waste through an integrated biorefinery at commercial level.
25. Compost Connect. (2024). What is industrial composting? https://www.compostconnect.org/what-is-industrial-composting
26. Sardarmehni, M., Levis, J. W., & Barlaz, M. A. (2021). What is the best end use for compost derived from the organic fraction of municipal solid waste? Environmental Science & Technology, 55(1), 73–81. https://doi.org/10.1021/acs.est.0c04997
27. Johannes, A. (2024). Compost blog: The ultimate guide to composting in a tumbler.
28. Caminati, V., et al. (2022). Collection and composting of organic waste: A case study in the city of Beira, Mozambique. International Journal of Environmental Impacts, 5(3), 259–270. https://doi.org/10.2495/EI-V5-N3-259-270
29. Lekkas, D. F., et al. (2022). Composting of the organic fraction of municipal solid waste as an alternative to the uncontrolled disposal: The case of Kalamata Municipality (Greece). Global NEST Journal, 24(1), 119–128. https://doi.org/10.30955/gnj.003486
30. Zoungrana, A., et al. (2014). Municipal solid waste composting: Case study of Istanbul. EurAsia Waste Management Symposium.
31. IGES & UNEP IETC. (2020). CCET guideline series on intermediate municipal solid waste treatment technologies: Composting.
32. Zero Food Waste Coalition. (2023). Achieving Zero Food Waste: A State Policy Toolkit. Available at: https://chlpi.org/news-and-events/news-and-commentary/news/zero-food-waste-coalition-highlights-state-policy-opportunities-to-reduce-food-waste/

Animal feed

33. Nath, P. C., Ojha, A., Debnath, S., Sharma, M., Nayak, P. K., Sridhar, K., & Inbaraj, B. S. (2023). Valorization of food waste as animal feed: A step towards sustainable food waste management and circular bioeconomy. Animals, 13(8), 1366. https://doi.org/10.3390/ani13081366
34. Harvard Law School Food Law and Policy Clinic. (2016). Leftovers for livestock: A legal guide for using excess food as animal feed. https://chlpi.org/wp-content/uploads/2013/12/Leftovers-for-Livestock_A-Legal-Guide_August-2016.pdf
35. USDA APHIS Veterinary Services. (n.d.). Performing Swine Health Protection Act (Garbage Feeding) Inspection. U.S. Department of Agriculture.
36. Food Standards Agency. (n.d.). The future of animal feed: Former foods, food waste and industry by-products and waste streams. https://www.food.gov.uk/research/the-future-of-animal-feed-former-foods-food-waste-and-industry-by-products-and-waste-streams
37. Kawashima, T. (2021). The use of food waste as a protein source for animal feed: Current status and technological development in Japan. Food and Agriculture Organization of the United Nations (FAO). https://www.fao.org/4/y5019e/y5019e0i.htm

38. One5C. (2024). Transforming food waste into animal feed. https://one5c.com/food-waste-animal-feed-136942045/
39. Rivin, J., Miller, Z., & Matel, O. (2013). Using food waste as livestock feed (A4069-02). University of Wisconsin-Extension. https://outagamie.extension.wisc.edu/files/2012/10/Using-Food-Waste-as-Livestock-Feed.pdf
40. USDA APHIS. (2024). Human food waste and swine: Protecting the health of the U.S. swine industry. U.S. Department of Agriculture.
41. U.S. Environmental Protection Agency. (n.d.). Excess food opportunities map. https://www.epa.gov/sustainable-management-food/excess-food-opportunities-map
42. USDA APHIS – Puerto Rico. (n.d.). Traditional waste feeding. U.S. Department of Agriculture – APHIS.
43. U.S. Environmental Protection Agency. (2009). Feeding animals: The business solution to food scraps. https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P1005N3W.txt
44. USDA APHIS – Puerto Rico Office. (n.d.). Cooking requirements. U.S. Department of Agriculture.
45. Van der Poel, A. F. B., Abdollahi, M. R., Cheng, H., Colovic, R., den Hartog, L. A., Miladinovic, D., Page, G., Sijssens, K., Smillie, J. F., Thomas, M., Wang, W., Yu, P., & Hendriks, W. H. (2020). Future directions of animal feed technology research to meet the challenges of a changing world. Animal Feed Science and Technology. https://doi.org/10.1016/j.anifeedsci.2020.114692

Anaerobic Digestion

46. Banks, C. J., Heaven, S., Zhang, Y., & Baier, U. (2018). Food Waste Digestion: Anaerobic Digestion of Food Waste for a Circular Economy. IEA Bioenergy Task 37. https://www.ieabioenergy.com/wp-content/uploads/2018/12/IEABioenergy_Task-37_Food-Waste_2Psummary-Rev-2.pdf
47. Mirmohamadsadeghi, S., Karimi, K., Tabatabaei, M., & Aghbashlo, M. (2019). Biogas production from food wastes: A review on recent developments and future perspectives. Bioresource Technology Reports, 7, 100202. https://doi.org/10.1016/j.biteb.2019.100202
48. Paritosh, K., Yadav, M., Mathur, S., Balan, V., Liao, W., Pareek, N., & Vivekanand, V. (2018). Organic Fraction of Municipal Solid Waste: Overview of Treatment Methodologies to Enhance Anaerobic Biodegradability. Frontiers in Energy Research, 6, 75. https://doi.org/10.3389/fenrg.2018.00075
49. Al-Wahaibi, A., Osman, A. I., Al-Muhtaseb, A. H., Alqaisi, O., Baawain, M., Fawzy, S., & Rooney, D. W. (2020). Techno-economic evaluation of biogas production from food waste via anaerobic digestion. Scientific Reports, 10, 15719. https://doi.org/10.1038/s41598-020-72897-5
50. Mohamed Ali, A., Alam, M. Z., Mohamed Abdoul-latif, F., Jami, M. S., Gamiye Bouh, I., Bello, I. A., & Ainane, T. (2023). Production of biogas from food waste using the anaerobic digestion process with biofilm-based pretreatment. Processes, 11(3), 655. https://doi.org/10.3390/pr11030655
51. Environmental and Energy Study Institute (EESI). (2017). Biogas: Converting Waste to Energy. https://www.eesi.org/papers/view/fact-sheet-biogasconverting-waste-to-energy
52. MEIKO GREEN Waste Solutions. (n.d.). Turning Food Waste into Fertiliser and Energy: Small-scale Biogas Plants for the Food Service Sector. Retrieved from https://www.meiko.com/en/meiko-experience/magazine/small-scale-biogas-plants-for-the-food-service-sector
53. HomeBiogas. (2024). How To Create Biogas From Food Waste. https://www.homebiogas.com/blog/biogas-from-food-waste/
54. Bioenergy Insight. (2016). Ecomaine launches a food waste recovery programme with biogas production. https://www.bioenergy-news.com/news/ecomaine-launches-food-waste-recovery-programme-with-biogas-production/

BioCovers

55. Climate Technology Centre & Network. (2016). Biocovers of landfills. Retrieved from https://www.ctc-n.org/technologies/biocovers-landfills
56. Kjeldsen, P., Kissas, K., & Scheutz, C. (2024). Do compost-based landfill biocover systems designed for methane oxidation emit nitrous oxide in significant amounts? Waste Management, 190, 506–510. https://doi.org/10.1016/j.wasman.2024.10.009

57. *Scheutz, C., Duan, Z., Møller, J., & Kjeldsen, P. (2023). Environmental assessment of landfill gas mitigation using biocover and gas collection with energy utilisation at aging landfills. Waste Management, 165, 40–50. https://doi.org/10.1016/j.wasman.2023.04.014*
58. *Center for Law, Energy & the Environment, University of California, Berkeley. (2022). Fighting climate change through landfill biocovers. Retrieved from https://cdss.berkeley.edu/project/fighting-climate-change-through-landfill-biocovers*
59. *Scheutz, C., Olesen, A. O. U., Fredenslund, A. M., & Kjeldsen, P. (2022). Revisiting the passive biocover system at Klintholm landfill, six years after construction. Waste Management, 145, 92–101. https://doi.org/10.1016/j.wasman.2022.04.034*
60. *Changing Markets Foundation, Environmental Investigation Agency, & Global Alliance for Incinerator Alternatives. (2022). Methane matters: A comprehensive approach to methane mitigation. Retrieved from https://changingmarkets.org/report/methane-matters-a-comprehensive-approach-to-methane-mitigation/*

Additional Resources

61. *Zero Waste to Zero Emissions. GAIA. (2002). https://www.no-burn.org/wp-content/uploads/2022/11/zero-waste-to-zero-emissions_full-report.pdf*
62. *Nair, Shibu. GAIA. (2022). Back to Earth: Composting for various contexts. https://www.no-burn.org/resources/back-to-earth/?fbclid=IwAR15pdcxbyfWxA0w1J-uULaZ0D_qP7KT_LexRQsXWQ7xt2hB2xM6Nv7ZTe8*
63. *ILSR. (2019) Community Composting Done Right: A Guide to Best Management Practices. . https://ilsr.org/composting-bmp-guide/*
64. *Hasiru Dala. (2019). Research and Publications. https://hasirudala.in/10-years-of-hasiru-dala/research-and-publications/*
65. *Hasiru Dala. (2020). Zero Waste Ward 177 Report. https://hasirudala.in/resources/documents/*
66. *Cambridge University Press. (s.f.). Hasiru Dala Innovations: Improving Lives of Waste Pickers. https://www.cambridge.org/core/services/aop-cambridge-core/content/view/36AF21C6809CB5FEDC264616BF64A0FD*
67. *End Plastic Waste. (s.f.). Integrating Waste Pickers into City Solid Waste Management Systems. From https://www.endplasticwaste.org/insights/story/how-to-integrate-waste-pickers-into-a-city-solid-waste-management-system*
68. *Mission Sustainability. (2024). Transforming Lives and Waste Management in Bengaluru - Hasiru Dala Innovations' Journey. From https://missionsustainability.org/blog/waste-management-in-bengaluru-hasiru-dala-innovations/*
69. *Hasiru Dala Innovations. (2023). Waste Management Company in Bangalore | Inclusive Circularity. https://hasirudalainnovations.com*
70. Malur, R., Kumuda, C. S., & Kumar, A. (2023, October 11). Stories of environmental justice values and principles for climate action: Hasiru Dala – India. Global Alliance for Incinerator Alternatives (GAIA). https://www.no-burn.org/blog-environmental-justice-hasiru-dala-india/
71. *Tamara Leisure Experiences. (2024). Empowering the Silent Environmentalists: How Waste Pickers Are Transforming Sustainability. //tamaraleisureexperiences.com/empowering-the-silent-environmentalists-how-waste-pickers-are-transforming-sustainability/*
72. *Tejas@IIMB. (s.f.). Hasiru Dala: Empowering the Waste Pickers (Case Study Report Part A). https://tejas.iimb.ac.in/articles/Hasiru%20Dala%20Case%20Study%20Report%20(Part%20A).pdf*
73. *City and County of San Francisco. (2012). San Francisco achieves 80 percent landfill diversion. https://sfmayor.org/article/mayor-lee-announces-san-francisco-reaches-80-percent-landfill-waste-diversion-leads-all*
74. *Recology. (n.d.). San Francisco's composting program. https://www.recology.com/recology-san-francisco/compost/*
75. *U.S. Environmental Protection Agency. (2025). Zero waste case study: San Francisco. https://www.epa.gov/transforming-waste-tool/case-study-san-francisco*

76. Gunders, D. (2012). San Francisco leads the way in composting. https://www.nrdc.org/sites/default/files/food-matters-san-francisco-composting-cs.pdf
77. CCAC (2025) Marketplace of Ideas. . https://www.canva.com/design/DAGfpK8z-ds/iV0Br2SW1lwrzq4tmejA1w/view?utm_content=DAGfpK8z-ds&utm_campaign=designshare&utm_medium=link2&utm_source=uniquelinks&utlId=h2c4216a9d4#1
78. FHI 360. (2024). Black soldier flies and "magic barrels" reduce community waste. Retrieved from https://www.fhi360.org/articles/black-soldier-flies-and-magic-barrels-reduce-community-waste
79. Jones, P. (2023). Cost-Benefit Analysis of the Early Morning Market Composting Pilot Project at the Durban Botanic Gardens: Final Report. Warwick Zero Waste Project. https://africazerowastehub.org.za/wp-content/uploads/2023/11/MunicipalSavingsCompostingCBA.pdf
80. Zero Waste Europe. (2016). Separate collection: The path to composting. Amigos de la Tierra Spain. https://zerowasteeurope.eu/downloads/separate-collection-the-path-to-composting/
81. Vieira, V. H. A. de M., & Ferreira dos Santos, L. (2023). Novos modelos de compostagem nas cidades: Integrando reciclagem, agricultura e moradia [PDF]. Instituto Pólis. https://www.no-burn.org/wp-content/uploads/2024/03/esp-Compostagem-nas-cidades-WEB.pdf
82. GAIA Global Alliance for Incinerator Alternatives. (2019). Community composting: Experiences from around the world [Webinar]. YouTube. https://www.youtube.com/watch?v=_BP3WyZKnKU
83. Allen, C., & Global Alliance for Incinerator Alternatives. (2023). Vegetable waste to zero waste in La Pintana, Chile. Other Worlds. https://www.no-burn.org/vegetable-waste-to-zero-waste-in-la-pintana-chile/
84. Boldrin, A., Andersen, J. K., Møller, J., Christensen, T. H., & Favoino, E. (2009). Composting and compost utilization: Accounting of greenhouse gases and global warming contributions. Waste Management & Research, 27(8), 800–812. https://doi.org/10.1177/0734242X09345275
85. Climate and Clean Air Coalition. (2024). CCAC case study: Linking waste management and protein production through insect technology. https://www.ccacoalition.org/news/ccac-case-study-linking-waste-management-and-protein-production-through-insect-technology
86. Ribeiro-Broomhead, J. & Tangri, N. (2021). ZeroWaste and Economic Recovery: The Job CreationPotential of Zero Waste Solutions. Global Alliance for Incinerator Alternatives. www.doi.org/10.46556/GFWE6885
87. Zero Food Waste Coalition. (2023) Achieving zero food waste: a state policy toolkit, https://cdn.sanity.io/files/34qvzoil/production/a517a31a81c38d76e897dd539bde3207affa164d.pdf
88. Climate and Clean Air Coalition. (2024). Transforming waste, sustaining the future: New guide on black soldier fly systems. https://www.ccacoalition.org/news/transforming-waste-sustaining-future-new-guide-black-soldier-fly-systems
89. Feed & Additive. (2023). Black soldier fly oil: A promising functional ingredient. https://www.feedandadditive.com/black-soldier-fly-oil-a-promising-functional-ingredient/
90. Witono, J. R., Setyadi, F. F., Deandra, P. P., & Wanta, K. C. (2024). A comprehensive analysis of chitin extraction from the black soldier fly for chitosan production. Chemical Engineering Transactions, 108, Article 23714. https://pp.omikk.bme.hu/ch/article/view/23714
91. Zhou, Y., Zhang, Y., & Wang, H. (2023). Environmental assessment of landfill gas mitigation using biocover and gas collection. Waste Management, 169, 1-10. https://www.sciencedirect.com/science/article/pii/S0956053X2300291X
92. Chavan, D., & Kumar, S. (2018). Reduction of methane emission from landfill using biocover as a biomitigation system: A review. https://www.researchgate.net/publication/326684740_Reduction_of_methane_emission_from_landfill_using_biocover_as_a_biomitigation_system_A_review
93. FAO. (2013). Manual de compostaje del agricultor: Experiencias en América Latina. Organización de las Naciones Unidas para la Alimentación y la Agricultura. Available at: https://www.fao.org/4/i3388s/i3388s.pdf
94. Brasil composta cultiva. (n.d.). Fortalecendo a gestão de resíduos orgânicos. Retrieved June 16, 2025, from https://brasilcompostacultiva.org.br/
95. Scharff, H., Soon, H.-Y., Taremwa, S. R., Zegers, D., Dick, B., Villas Bôas Zanon, T., & Shamrock, J. (2023). The impact of landfill management approaches on methane emissions. Waste Management & Research, 1–13. https://doi.org/10.1177/0734242X231200742

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GAIA is a network of grassroots groups as well as national and regional alliances representing more than 1000 organizations from over 100 countries. With our work we aim to catalyze a global shift towards environmental justice by strengthening grassroots social movements that advance solutions to waste and pollution. We envision a just, Zero Waste world built on respect for ecological limits and community rights, where people are free from the burden of toxic pollution, and resources are sustainably conserved, not burned or dumped. www.no-burn.org

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