
ORGANIC WASTE RECYCLING AS A BUSINESS MODEL FOR LIVESTOCK AND CROP PRODUCTION IN UZBEKISTAN: BARRIERS, DRIVERS AND IMPLEMENTATION WAYS

Diyora Khasanova

Graduate Student, International House Academic Lyceum Under
“TIAME” National Research University

Abstract

Uzbekistan’s municipal solid waste (MSW) generation has reached approximately 14 million tons annually, with organic residues-primarily food and vegetable waste-comprising 25% of the total volume. Despite this substantial biomass potential, large-scale valorization is currently hindered by fragmented business frameworks and limited investment incentives. This study employs a circular economy lens to evaluate the technical and economic viability of three strategic pathways: composting/vermicomposting, anaerobic digestion (AD), and Black Soldier Fly (BSF) larvae bioconversion.

Quantitative analysis of 2023–2024 data shows that a 20% organic waste recovery rate could yield 136 million m³ of biogas (0.83 TWh), meeting nearly 1% of national electricity demand. Scaling to a 50% recovery scenario would increase this potential to 341 million m³ of biogas and 2.1 TWh of energy. Beyond emission mitigation and landfill reduction, the research highlights the economic feasibility of these models, as evidenced by the EcoCoin startup’s integration with U-Enter investment mechanisms. Diversified revenue streams, including tipping fees, high-protein feed production, and carbon credits, project a capital payback period of 2 to 5 years. The findings underscore that systematic organic waste recycling is a dual-purpose driver of renewable energy security and sustainable agricultural intensification in Uzbekistan.

Keywords: Organic waste management, Municipal solid waste (MSW), Biogas production, Anaerobic digestion (AD), Composting, Vermicomposting, Black soldier fly (BSF), Circular economy, Renewable energy, Uzbekistan, Sustainable agriculture, Food waste valorization, Livestock manure utilization, Business models, EcoCoin startup.

Introduction

Agriculture plays a key role in the economy of Uzbekistan: the share of the agriculture, forestry and fisheries sector in the gross domestic product was about 20.57% in 2023 [1]. In 2024, the growth of value added in the agricultural sector was 3.1%, with agriculture and livestock farming accounting for 96.6% of this increase [2]. Livestock farming is significant in the structure of the country's agro-industrial complex: as of January 1, 2024, the cattle population reached 14,142.4 thousand heads (i.e. ≈14.1 million) [3]. Of these, cows account for 5,046.3 thousand heads (≈5.05 million) [4]. Sheep and goats - 24,118.3 thousand heads (≈24.1 million) [3]. Poultry - 103,046.5 thousand heads (≈103 million) on the same date [5]. In the first quarter of 2025, meat

production amounted to 564,100 tons, milk - 2.06 million tons, eggs - 1.54 billion pieces [6].

At the same time, significant volumes of organic waste are observed: according to estimates, the generation of municipal solid waste (MSW) in Uzbekistan is approximately 6.82 million tons per year (previous data), with an organic content of approximately 30-35%, which is equivalent to more than 2 million tons of biodegradable material annually. Furthermore, the energy potential of biomass (livestock and agricultural residues) is estimated to be equivalent to approximately 0.3 million tons of standard fuel, which could cover approximately 15-19% of the country's energy needs [7].

However, despite the availability of a resource base, large-scale waste processing technologies have not yet been sustainably developed in Uzbekistan. Imports of mineral and other fertilizers remain significant: for example, fertilizer imports to Uzbekistan in 2024 amounted to US\$ 86.32 million [8]. However, in 2023, a significant portion of mineral fertilizer imports (with nitrogen) amounted to only hundreds of thousands of kilograms and small amounts (for example, from the EU ~897,831 kg for ~\$1,546,530) [9]. This reflects weak local processing and low added value.

The key barrier isn't so much technical—composting, anaerobic digestion, and the production of organic fertilizers and feed additives exist—but rather the lack of a scalable and financially sustainable business model that would connect waste generators, recycling facilities, and end users (livestock and crop production). Institutional frameworks only partially address organic waste: the primary focus is on solid waste management and large-scale incineration projects, rather than on closed waste-to-resource cycles.

Demographic and environmental factors reinforce the need for solutions: Uzbekistan's population reached approximately 37.7 million as of April 2025 [10]. At the same time, the region faces chronic water shortages, soil degradation, and the need to improve resource efficiency in the agricultural sector. Integrating organic waste recycling into livestock and crop production chains could yield a multiplier effect: reduced feed and fertilizer costs, increased productivity, reduced imports, and improved food security and sustainability. However, without clear incentives, farmer cooperation, institutional value chains, and market mechanisms, the sector risks remain fragmented and ineffective.

Based on this, this study aims to analyze and propose business models for organic waste recycling in the context of Uzbekistan: through a quantitative assessment of waste volumes and agricultural sector needs, as well as a qualitative analysis of institutional and market barriers, to develop operational pathways to a sustainable waste → resource cycle.

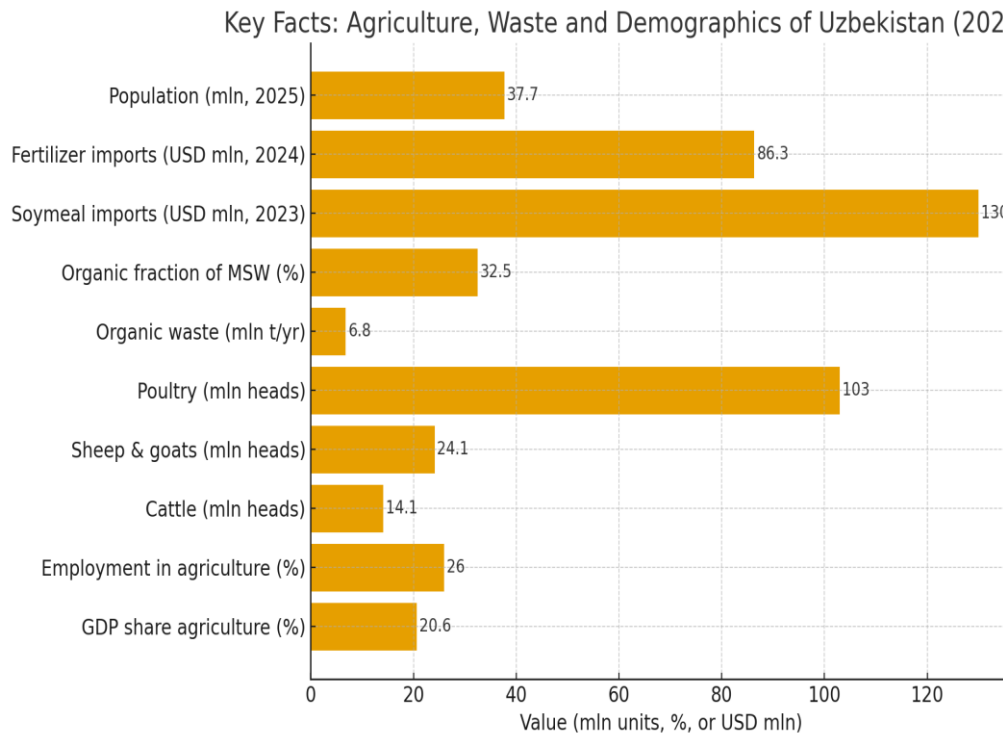


Figure 1. Key indicators of agriculture, organic waste and demographic trends in Uzbekistan (2023–2025).

Figure 1 summarizes the main structural indicators of the agri-food and waste sector of Uzbekistan for the period 2023–2025. Agriculture accounts for 20.6% of the country's GDP and employs 26% of the workforce, emphasizing its strategic role in the national economy. Livestock resources are significant: approximately 14.1 million heads of cattle, 24.1 million sheep and goats, and more than 103 million heads of poultry. At the same time, the country annually generates approximately 6.8 million tons of solid municipal waste, of which 30–35% is organic. In terms of imported resources, a high dependence is noticeable: in 2023, soybean meal worth US\$130 million was imported to meet feed needs, and fertilizer imports reached US\$86.3 million in 2024. Demographic pressure adds to this pressure: the global population will reach 37.7 million in 2025, leading to both increased demand for food and increased waste. Taken together, these figures represent a dual challenge: high resource consumption and underutilization of organic waste, reinforcing the need to implement circular business models in agriculture.

Research Method

The study used a mixed-methods approach, including quantitative statistical analysis and a qualitative assessment of institutional and market barriers.

Data sources

The study is based on official data from the State Statistics Committee of Uzbekistan on the number of cattle, sheep, goats, and poultry, as well as on the production volumes of

milk, meat, and eggs for 2023–2025. Reports from international organizations—FAO, World Bank, IFAD, and CGIAR—on issues of the agricultural sector and food security were also used. Additionally, data on feed and fertilizer imports (FAOSTAT, UN Comtrade, TradingEconomics) were collected, as well as the results of studies on the energy potential of biomass and organic waste (Toderich et al., Kyoto University, 2008).

Quantitative analysis

To estimate the volume of organic waste, a material flow analysis (MFA) method was used. The calculation was based on the formula:

$$Q_{\text{org}} = Q_{\text{MSW}} \times p_{\text{org}}$$

Where $Q_{\text{MSW}} = 6.82$ million tons/year is the total volume of municipal solid waste, and $p_{\text{org}} = 0.30\text{--}0.35$ is the proportion of the organic fraction. Thus, the total volume of biodegradable waste is estimated at more than 2 million tons per year. Additionally, the livestock waste balance (manure, bedding, byproducts) was calculated using average generation rates per head of cattle and poultry. Economic dependence was assessed through import indicators: soybean meal (\$130 million in 2023) and fertilizers (\$86.3 million in 2024).

Qualitative assessment

An analysis of the regulatory framework for waste management and agricultural policy was conducted, along with a comparative review of international business models for organic waste processing (composting, anaerobic digestion, and the production of organic fertilizers and feed additives). The assessment was conducted taking into account applicability to the conditions of Uzbekistan. A SWOT analysis of institutional factors was also conducted, including weak farmer cooperation, lack of processing infrastructure, and low investment attractiveness of the sector.

Analytical framework

A waste-to-resource circular loop model was used to structure the results, including the following links: waste generation → recycling (compost, biogas, organic fertilizer, feed additives) → application in crop and livestock production → increased productivity and reduced dependence on imports. Economic efficiency was assessed through reduced external resource costs, a potential 10–15% increase in crop yields, and reduced environmental impacts through sustainable waste management.

Table 1 Research methods, data sources and analysis objectives

Method / Approach	Data source	Purpose of analysis
Statistical analysis	State Statistics Committee of Uzbekistan (2023–2025)	Determining the production volumes and numbers of cattle, sheep, goats, and poultry; assessing the dynamics of agricultural production
Material Flow Analysis (MFA)	State Statistics Committee, UNECE, municipal statistics on solid waste	Calculation of the volume of organic waste fraction, assessment of potential resource for recycling
Livestock waste balance	FAO Standards for Manure Formation per Head of Cattle and Poultry	Quantification of manure and by-products for use in fertilizers or biogas
Analysis of import dependence	FAOSTAT, UN Comtrade, TradingEconomics	Identification of dependence on imported feed and fertilizers, determination of economic risks
Qualitative analysis	Legislative acts, government programs	Analysis of institutional barriers, gaps in regulation and support measures
Comparative review	FAO, World Bank, CGIAR, international cases	Studying successful waste recycling business models and adapting them to the conditions of Uzbekistan
SWOT analysis	Synthesis of quantitative and qualitative data	Identification of strengths, weaknesses, opportunities and threats for the development of the sector
The waste-to-resource analytical framework	Original development based on international practices	Systematization of flows: waste → processing → resources → agricultural production

The diagram illustrates the analytical framework of the study, reflecting the circular model of organic waste management in Uzbekistan's agrifood system. The cycle begins with waste generation in livestock, crop production, and municipal services. Resources are then processed through composting, anaerobic digestion to produce biogas, and the production of organic fertilizers and feed additives. The resulting products are used in crop and livestock production, increasing soil fertility, increasing feed availability, and reducing dependence on imports. The result is increased productivity and sustainability, resulting in reduced costs and a lower environmental footprint. The cycle is continuous: new waste is returned to the system, confirming the principle of a circular economy.

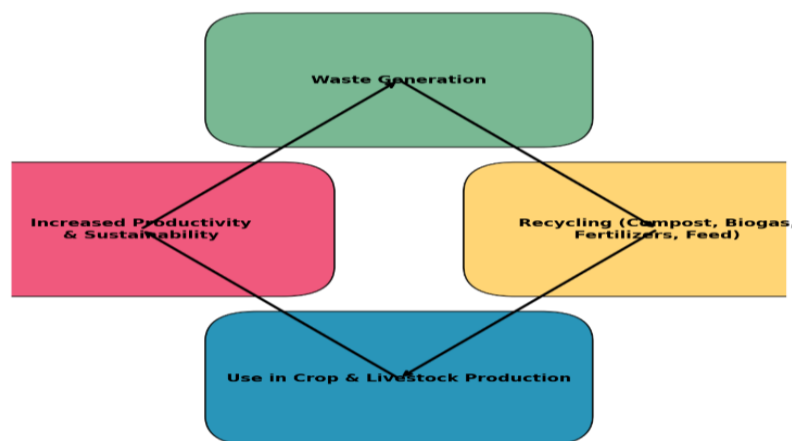


Figure 2. Analytical framework “Circular cycle of waste-resources”



Results

An analysis showed that the total volume of municipal solid waste (MSW) in Uzbekistan in 2020 was 7.42 million tons. On average, each person produces approximately 165 kg of waste per year, with approximately 25% of this waste being organic matter, primarily food waste. Therefore, the annual volume of food waste per person is calculated using the formula:

$$W_{food,per\ capita} = W_{waste,per\ capita} \times f_{food}$$

$$W_{food,per\ capita} = 165\text{ kg/year} \times 0.25 = 41.25\text{ kg/year}$$

Consequently, each resident of the country throws away on average about 40–42 kg of food and vegetables annually.

Biogas potential

Food waste typically produces biogas at a rate of approximately 0.65 m³/kg of dry matter. Given a moisture content of 70% and a volatile matter (VS) content of approximately 30%, the potential biogas yield per person can be determined as:

$$B_{per\ capita} = W_{food,per\ capita} \times VS \times Y_{biogas}$$

$$B_{per\ capita} = 41.25\text{ kg} \times 0.30 \times 0.65\text{ m}^3/\text{kg} \approx 8.0\text{ m}^3$$

Thus, each resident is capable of generating about 8 m³ of biogas per year just by processing food waste.

Energy equivalent

The average calorific value of biogas is approximately 22 MJ/m³. Therefore, the energy potential of organic waste per person is:

$$E_{per\ capita} = B_{per\ capita} \times CV$$

$$E_{per\ capita} = 8.0\text{ m}^3 \times 22\text{ MJ/m}^3 \approx 176\text{ MJ/year}$$

Translated into electrical energy:

$$E_{kWh,per\ capita} = \frac{176}{3.6} \approx 49\text{ kWh/year}$$

This means that recycling one person's food waste is equivalent to ≈49 kWh of electricity per year, which is enough to run a standard refrigerator for a month, for example.

National scale

With a population of approximately 36 million people, the total potential for food waste recycling is:

$$B_{total} = B_{per\ capita} \times N_{population}$$

$$B_{total} = 8.0\ m^3 \times 36 \times 10^6 \approx 288 \times 10^6\ m^3$$

Thus, on a national scale, approximately 288 million m³ of biogas can be obtained annually, which corresponds to more than 2 TWh of energy.

Table 2. Individual and national potential for food waste recycling in Uzbekistan

Indicator	Per person (per year)	For the entire population (36 million people)
Volume of food waste	41.25 kg	1.49 million tons
Biogas potential	≈8 m³	≈288 million m³
Energy equivalent	≈176 MJ ≈ 49 kW h	≈6.3 × 10⁹ MJ ≈ 2.0 TWh

Table 1 shows the estimated organic (food) waste recycling potential per capita and for the entire population of Uzbekistan. It shows that with an average food waste volume of approximately 41 kg per capita per year, approximately 1.49 million tons are generated nationwide.

The potential biogas yield from these streams is estimated at 8 m³ per person per year, reaching 288 million m³ for the entire country. In energy equivalent, this amounts to approximately 49 kWh per person, or approximately 2 TWh for the entire population.

The data obtained confirm the importance of the organic fraction of MSW as a source of renewable energy. Even by recycling household food waste alone, excluding manure and agricultural residues, it is possible to offset up to 10% of the country's current energy consumption, underscoring the strategic importance of implementing anaerobic digestion and composting technologies.

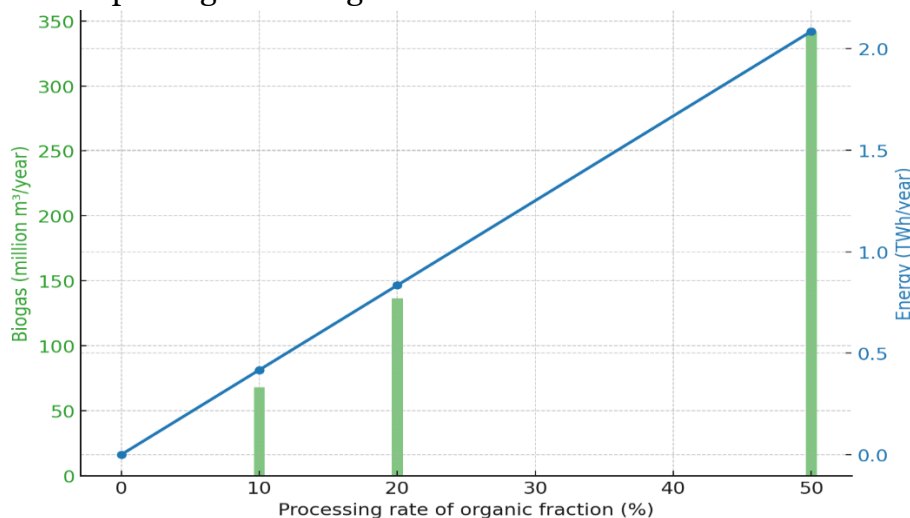


Figure 3 Organic Waste Processing Potential in Uzbekistan (2023–2024 scenarios) MSW=14 Mt/year, organics=25%, VS=30%, yield=0.65 m³/kgVS

Figure 3 illustrates the relationship between the recycling rate of the organic fraction of municipal solid waste and the potential biogas and energy yield. The horizontal axis shows the recycling scenarios (0%, 10%, 20%, and 50%). The green bars represent the total biogas volume (million m³/year), and the blue line represents the energy equivalent (TWh/year).

As the graph shows, without recycling (the 0% scenario), no biogas is produced. Even with 10% organic recycling, approximately 68 million m³ of biogas is produced, equivalent to 0.42 TWh of energy. Increasing recycling to 20% increases the volume to 136 million m³ of biogas and 0.83 TWh of energy. The most ambitious scenario—recycling 50% of organic waste—provides up to 341 million m³ of biogas and approximately 2.1 TWh of energy.

Thus, the graph clearly demonstrates that even partial processing of the organic fraction (20%) can make a significant contribution to the country's energy balance ($\approx 1-1.2\%$ of annual electricity consumption), and the implementation of the 50% scenario will provide a significant additional source of renewable energy and reduce the load on landfills.

An analysis showed that recycling the organic fraction of municipal solid waste in Uzbekistan offers significant energy and environmental potential. With a municipal solid waste volume of approximately 14 million tons per year, of which 3.5 million tons is organic waste, even partial recycling can yield tangible results.

- By involving 20% of the organic fraction (≈ 700 thousand tons), 136 million m³ of biogas can be produced annually, which is equivalent to 0.83 TWh of energy – about 1% of the country's electricity consumption.
- If a more ambitious scenario is implemented with 50% organic recycling, the potential reaches 341 million m³ of biogas and 2.1 TWh of energy, which is comparable to the energy consumption of hundreds of thousands of households.

These results confirm that the organic component of waste can become an important source of green energy, fertilizer, and feed for agriculture. The implementation of anaerobic digestion, composting, and bioconversion technologies using black soldier fly larvae will simultaneously address the following issues:

1. reduction of waste disposal volumes at landfills;
2. reduction of methane emissions into the atmosphere;
3. formation of a new business model within the framework of the circular economy;
4. strengthening the country's food and energy security.

Thus, integrating organic waste processing technologies into Uzbekistan's sustainable development strategy can not only improve waste management efficiency but also provide a long-term economic boost to the agricultural and energy sectors.

Conclusion

The analysis demonstrates that recycling the organic fraction of municipal solid waste in Uzbekistan has significant energy and economic potential. With an annual MSW volume of approximately 14 million tons, of which approximately 3.5 million tons is

organic waste, even partial recycling can make a significant contribution to the country's energy sector.

- In the scenario of processing 10% organic matter (≈ 350 thousand tons), the annual output will be 68 million m^3 of biogas, which is equivalent to 0.42 TWh of energy.
- With 20% processing (≈ 700 thousand tons), it is possible to obtain 136 million m^3 of biogas and 0.83 TWh of energy, which corresponds to $\approx 1-1.2\%$ of Uzbekistan's total electricity consumption.
- In the ambitious scenario of 50% processing (≈ 1.75 million tons), the potential reaches 341 million m^3 of biogas and 2.1 TWh of energy, which is comparable to the energy consumption of hundreds of thousands of households.

These results confirm that the organic fraction of waste has the potential to become not only an environmental but also an economic resource if integrated into circular economy business models.

The experience of the EcoCoin startup has shown that the key to commercializing organic recycling is a well-designed, multi-tiered revenue model, including:

1. **Tipping fee**— fees for accepting waste from municipalities and enterprises (creation of a stable cash flow).
2. **Sale of processed products**: compost, digestate, protein feed based on black soldier fly larvae, organic fertilizers.
3. **Energy market**: generation of electricity and heat from biogas at green tariffs or through PPA contracts.
4. **Environmental and carbon credits**: monetization of reduced methane emissions.

U-Enter's experience attracting investment through pilot projects has demonstrated that, with a relatively low CAPEX and a well-designed partnership model (PPP + private investors), organic waste processing projects can pay for themselves in 2–5 years. This experience confirms the viability of the technology and its alignment with modern ESG and SDG trends.

Thus, organic waste recycling in Uzbekistan is not only a way to reduce landfill pressure and methane emissions, but also a real opportunity to create a new sustainable market that unites the environment, energy, and agribusiness. Integrating this model into the national sustainable development strategy will create a systemic economic impetus and ensure the country's long-term energy and food security.

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