ECO-FRIENDLY ORGANIC WASTE MANAGEMENT IN THE EUROPEAN UNION AND UKRAINE: CURRENT STATE AND POTENTIAL

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The article examines the current state, potential, and future prospects of eco-friendly processing of organic waste in the European Union (EU) and Ukraine. It highlights the critical role of organic waste recycling in sustainable development, circular economy, and environmental protection. The best European pactices in waste prevention, reuse, recycling, and energy recovery, which serve as benchmarks for Ukraine's waste management reforms, were analysed. The study also analyzes Ukraine's organic waste processing potential, focusing on agricultural residues, food industry by-products, and biodegradable municipal waste. Findings demonstrate that adopting an integrated approach to organic waste management can reduce environmental risks and greenhouse gas emissions, stimulate renewable energy production, enhance energy security, and support rural development. The article emphasizes that by adapting EU best practices, Ukraine has significant opportunities to strengthen its sustainability and move toward a resource-efficient circular economy model.

Keywords: organic waste, circular economy, renewable energy, anaerobic digestion, European sustainability

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Introduction

Organic waste presents both significant challenges and considerable opportunities for sustainable waste management, renewable energy production, and climate change in the European Union (EU) and Ukraine. Bio-waste-comprising household food waste, garden waste, and other biodegradable municipal waste-constitutes approximately 34% of municipal solid waste in the EU (European Environment Agency, 2024). Currently, only about 40% of this bio-waste (approximately 47.5 million tonnes annually) is separately collected and processed into compost or digestate via biological treatment (European Compost Network, 2024).

Ukraine also possesses substantial organic waste and biomass potential. For example, according to UABIO's "Bioenergy in Ukraine until 2030" report, Ukraine's total biogas/biomethane energy potential is estimated at 21.8 billion cubic metres (bcm) annually, equivalent to roughly 18.7 million tons of oil equivalent (toe) per year (UABIO, 2024). Key feedstocks include agricultural residues (e.g., crop residues, straw, husks), food industry by-products, animal manure, and biodegradable municipal organic waste. Some studies indicate that agricultural biogas feedstock

alone could yield up to approximately 8.8 bcm of biomethane annually, potentially substituting a significant share of natural gas imports in Ukraine (Vaskina et al., 2025).

Despite this considerable potential, organic waste utilization remains suboptimal in both regions. Although EU policies mandate separate bio-waste collection under the Waste Framework Directive, many member states face challenges in establishing effective collection, treatment, and valorisation systems (Bio-Based Industries Consortium, 2024). In Ukraine, barriers include regulatory uncertainty, limited investment in waste processing infrastructure, technical constraints, and socio-economic challenges.

This paper aims to compare and characterize the potentials for eco-friendly organic waste processing in the EU and Ukraine, identify main barriers to scaling up composting, anaerobic digestion, and biomethane production in Ukraine, and propose policy recommendations based on EU best practices.

Organic waste management in the European Union

The European Union has made more advanced significant progress in organic waste management, albeit with ongoing challenges. The European Environment Agency (EEA, 2024) reports a municipal waste recycling rate of 49% in 2022, with packaging waste recycling reaching 65%. Nevertheless, studies by Zero Waste Europe and the Bio-based Industries Consortium reveal that approximately 74% of food waste in the EU is still landfilled or incinerated, underscoring the need for further enhancement of organic waste management systems (Zero Waste Europe, 2024; Bio-Based Industries Consortium, 2024).

These data affirm that although the EU has established comprehensive waste processing infrastructures, both the EU and Ukraine must continue to improve collection, treatment, and valorisation systems to fully harness organic waste's potential as a renewable resource.

The transition toward a circular bioeconomy within the EU has accelerated the development and deployment of bioenergy technologies for valorising agricultural residues such as straw, maize stover, sunflower husks, and animal manure. These biomass streams, once regarded as low-value by-products, are increasingly utilized as sustainable feedstocks for energy generation and soil fertility enhancement.

Anaerobic digestion (AD) remains the foundational technology for biogas production throughout the European Union. It is especially suited to animal manure and other wet substrates, with its efficiency enhanced by co-digestion with crop residues such as straw or maize stalks following appropriate pretreatment. This process produces biogas, which can be upgraded to biomethane for injection into natural gas grids or direct use as a transport fuel. Alongside energy recovery, the digestate functions as a nutrient-rich fertilizer, promoting circular nutrient management and reducing reliance on synthetic fertilizers (UABIO, 2024; Vaskina et al., 2024).

For lignocellulosic residues, characterized by lower biodegradability, thermochemical pathways including pyrolysis, gasification, and torrefaction are increasingly employed. These technologies enable the production of syngas, bio-oil, and biochar, thereby broadening the range of renewable energy carriers and carbon-based materials available to European markets (European Biogas Association, 2024). Sunflower husks, notable for their high calorific value and low moisture content, are particularly well-suited to direct combustion, pelletization, or gasification (Bio-Based Industries Consortium, 2024).

Aerobic processes complement these approaches. Industrial-scale composting, whether conducted via in-vessel or open windrow systems, remains widespread for drier biomass streams and mixed organic wastes. Compost production not only diverts biodegradable fractions from landfills and incinerators but also enhances soil health through the return of organic matter and nutrients (European Compost Network, 2024; European Environment Agency, 2024).

Despite these technological advances, significant challenges persist. High pretreatment costs for lignocellulosic residues, logistical barriers linked to seasonal feedstock variability and transportation, and the necessity for consistent policy support limit broader deployment. Nevertheless, the EU's Waste Framework Directive and subsequent bio-waste regulations have established a robust policy framework that encourages investment and technology adoption, aligning waste management with climate and renewable energy objectives (European Parliament & Council of the European Union, 2008).

The management of the organic fraction of municipal solid waste (OFMSW) has become a strategic priority in the European Union, reflecting commitments to circular economy principles and greenhouse gas mitigation. Organic waste constitutes approximately one third of the municipal waste stream, and its ecological treatment is increasingly recognized as essential for climate policy and resource recovery (European Environment Agency, 2024).

A central component of the EU's strategy is the implementation of source-separated collection schemes, which significantly improve feedstock quality for subsequent processing. In municipalities with rigorous separation, contamination by plastics and inert materials is minimized, thereby enhancing the efficiency of biological treatments such as composting and anaerobic digestion (European Compost Network, 2024). In regions where collection systems remain underdeveloped, mixed waste fractions often necessitate mechanical pretreatment, resulting in higher costs and reduced output quality.

In summary, the integration of anaerobic, thermochemical, and composting technologies exemplifies a diversified strategy for agricultural residue utilization within the EU. While manure digestion and composting are well-established, scaling up advanced thermochemical and pretreatment techniques is essential to fully exploit the potential of lignocellulosic feedstocks. This technological convergence is pivotal to meeting decarbonisation targets and advancing sustainable agricultural resource management.

Challenges of organic waste management in Ukraine

In Ukraine, organic waste processing remains at an early developmental stage. Recent studies report that the municipal waste recycling rate ranges between 3% and 8%, indicating that over 90% of waste is still disposed of in landfills or illegal dumpsites (Switch to Green, 2025). In 2020, Ukraine generated approximately 462 million tonnes of waste, with municipal waste comprising only 1.3%. The recycling rate for municipal waste was merely 9.9%, highlighting significant gaps in sustainable waste management (Woima Corporation, 2024).

However, some positive initiatives have emerged. For example, Lviv operates a municipal composting facility that converts organic waste into high-quality compost for local agricultural use. This facility exemplifies how municipal organic waste valorisation can support local farming while mitigating environmental impacts (Grynchyshyn et al., 2025; Climate Adapt Platform, 2023).

Ukraine is actively adopting modern bioenergy technologies to process agricultural waste, including straw, corn stalks, sunflower husks, and animal manure. The nation possesses significant

biomass energy potential; according to the Bioenergy Association of Ukraine, as of 2018, this potential amounted to 23 million tons of oil equivalent (toe), with crop residues contributing 10 million toe (44%) and energy crops 7.5 million toe (32%) (UABIO, 2018).

Ukraine is expanding biofuel production including bioethanol, biodiesel, and biogas using agricultural residues and energy crops. Biomethane production not only provides a renewable energy source but also yields digestate, an organic fertilizer valuable to agriculture (SAF, 2024).

The development of Ukraine's bioenergy sector is poised to strengthen energy independence. The biomethane sector alone could generate export revenues up to €1.24 billion by 2030 (Low Carbon Ukraine, 2024). Investments in bioenergy can stimulate rural development, create employment opportunities, and reinforce national energy security.

Employing an integrated approach to agricultural waste processing can mitigate environmental impacts while fostering economic growth. Ukraine's extensive gas infrastructure facilitates the deployment of biomethane plants nationwide, including rural areas. The establishment of sustainable bioenergy clusters can replace imported energy sources and contribute to national energy sovereignty.

Ukraine has distinctive opportunities to transform agricultural waste into valuable energy resources. Prioritizing biofuel production and the development of sustainable bioenergy clusters will reduce environmental impacts, bolster energy security, and stimulate economic growth. Thus, an integrated approach to agricultural waste processing is both environmentally advantageous and a catalyst for Ukraine's economic development.

Discussion

Among biological pathways, anaerobic digestion is particularly effective for wet organic substrates such as food scraps and garden residues. AD facilitates biogas production that can be upgraded to biomethane for use in gas grids or as renewable transport fuel, while the digestate serves as a nutrient-rich fertilizer, supporting sustainable nutrient management in agriculture (Municipal Waste Europe, n.d.). Composting remains the dominant method for drier organic materials and mixed green waste. Large-scale aerobic composting facilities across Europe produce stable compost that improves soil fertility and contributes to long-term carbon sequestration. Evidence suggests these systems also reduce methane emissions relative to landfilling, underscoring their role in meeting climate objectives (European Compost Network, 2024; Zero Waste Europe, 2024).

Recently, thermochemical conversion methods have been explored as complementary technologies to conventional biological processes. Techniques such as hydrothermal carbonization, pyrolysis, and gasification enable the valorization of resistant fractions, including contaminated or lignocellulosic wastes, generating syngas, bio-oil, or biochar. These products diversify the EU's renewable energy carrier portfolio and provide additional carbon storage options through soil application of biochar (Zero Waste Europe, 2024). Hybrid systems combining anaerobic digestion with downstream thermochemical conversion of digestate are emerging as promising innovations to enhance overall system efficiency.

Despite technological progress, several barriers to large-scale implementation remain. These include seasonal fluctuations in waste availability, inadequate infrastructure in some Member States, and limited market demand for compost or digestate, all of which impact the economic viability of treatment facilities. Furthermore, public acceptance and harmonized quality standards for recycled products vary, necessitating regulatory consistency and ongoing awareness efforts. The Waste

Framework Directive (Directive 2008/98/EC) and related policies form the cornerstone of EU waste legislation, compelling Member States to prioritize prevention, recycling, and valorization over disposal and thereby fostering an enabling environment for continued innovation (European Parliament & Council of the European Union, 2008).

The ecological treatment of organic municipal waste in the European Union exemplifies the convergence of biological and thermochemical technologies within a policy framework increasingly oriented toward resource recovery. While composting and anaerobic digestion are well-established, scaling up emerging hybrid and thermochemical techniques remains essential to fully realize the organic waste stream's potential. This transition reflects the broader EU paradigm shift from disposal-focused waste management to circular resource use, climate neutrality, and soil health enhancement.

In contrast, the recycling of the organic fraction of municipal solid waste in Ukraine is at an early developmental stage compared to the EU. Organic waste, primarily food residues, green waste, and biodegradable industrial by-products, accounts for over 40% of Ukraine's municipal solid waste stream (State Statistics Service of Ukraine, 2023). Nevertheless, most of this fraction is landfilled, resulting in uncontrolled methane emissions, leachate production, and consequent soil and groundwater contamination (World Bank, 2020).

Attempts to implement separate collection of biodegradable waste have been limited, focusing mainly on large urban centers such as Kyiv, Lviv, and Kharkiv. Pilot projects demonstrate that source separation markedly enhances organic feedstock quality for biological processing. However, insufficient infrastructure and low public awareness hinder widescale adoption (Ministry of Environmental Protection and Natural Resources of Ukraine, 2022). Presently, only a few municipal composting and anaerobic digestion facilities operate nationwide, with processing capacities covering less than 5% of organic waste generation.

Among treatment methods, anaerobic digestion (AD) emerges as the most promising for Ukraine, simultaneously addressing waste management and renewable energy needs. Produced biogas can be converted into heat, electricity, or upgraded biomethane, which is particularly pertinent given Ukraine's ongoing energy security challenges (International Energy Agency, 2023). Composting facilities, though less prevalent, contribute positively to soil fertility improvement—an especially important factor considering Ukraine's agricultural economy. Nevertheless, challenges remain in aligning compost quality and digestate use with EU standards as part of Ukraine's European integration commitments (European Commission, 2022).

Ukraine's legal framework has been strengthened through the 2023 adoption of the Law "On Waste Management," harmonizing national policy with EU Directive 2008/98/EC. This legislation enshrines the waste management hierarchy, prioritizing prevention, reuse, and recycling over landfilling, and introduces extended producer responsibility (EPR) mechanisms (Verkhovna Rada of Ukraine, 2023). Effective implementation will, however, require substantial infrastructure investment and capacity building among local authorities and stakeholders.

In conclusion, while legislative progress toward sustainable waste management in Ukraine is evident, practical recycling of OFMSW remains limited. Expansion of composting and anaerobic digestion, supported by improved collection systems and public education, will be vital to achieving environmental and energy objectives. Ukraine's integration into the EU waste management framework is expected to accelerate these developments, contingent on addressing financial, institutional, and technological challenges systematically.

Organic waste management – including food scraps, agricultural residues, and garden waste – constitutes a critical component of sustainable development strategies in both the EU and Ukraine. Accounting for up to 50% of municipal solid waste in the EU and 60% in Ukraine, organic waste disproportionately contributes to landfill methane emissions, which represent 8–10% of global greenhouse gases (European Environment Agency, 2023a). Eco-friendly processing technologies, such as anaerobic digestion for biogas and composting for nutrient-rich soil amendments, convert these wastes into valuable resources consistent with the EU Circular Economy Action Plan and Ukraine's National Waste Management Strategy through 2030 (European Commission, 2020).

Processing organic waste also avoids significant landfilling costs, which averaged €109 per tonne in full lifecycle expenses across the EU-27 in 2023 (Martinho et al., 2023). By diverting bio-waste, municipalities save on landfill taxes – ranging from €3 to €150 per tonne – and reduce methane capture costs. Anaerobic digestion facilities in the EU produce biogas equivalent to 2–5% of natural gas consumption, generating approximately €400 million annually in energy sales and offsetting 2 million tonnes of CO_2 emissions (Ecostar, 2024). Compost production reduces fertilizer imports by 10–15%, saving €200–300 million annually in agricultural expenditures (European Compost Network, 2023).

The recycling sector, including organic waste processing, supports around 500,000 direct jobs in the EU, with organic waste accounting for 20% through specialized roles in collection, treatment, and distribution (EEA, 2011). Countries like Germany and Denmark have implemented source-separation initiatives that created approximately 2,700 jobs per major project and boosted local economies by €1.5 billion in value-added output (Boldrin et al., 2016). Life-cycle assessments suggest that scaling organic recycling could result in 206,100 new EU jobs by 2030, yielding a net economic benefit of €8.4 billion through avoided environmental costs (Martinho et al., 2023).

These advantages are further enhanced by market demand for bioproducts. The EU fertilizer market, valued at €30 billion, increasingly incorporates recycled organic materials, thereby improving competitive positioning (European Commission, 2018).

Ukraine generates between 10 and 12 million tonnes of organic waste annually, predominantly from agriculture and households; however, only 4–6% is currently processed, with approximately 93% disposed of in landfills (Food and Agriculture Organization, 2018; Sayenko Kharenko, 2023). Nevertheless, emerging initiatives demonstrate economic viability, notably biogas production from livestock waste.

Operational biogas plants at four major Ukrainian farms since 2012 process manure to produce an annual equivalent of 2.6 billion cubic meters of natural gas, potentially generating €150–200 million in energy revenues. Pilot composting projects in Lviv and Kyiv have reduced landfill expenses by 20–30% (equivalent to €10–15 per tonne) while producing compost marketed at €50–70 per tonne for soil restoration (Shen, 2019; Waste Recycling Association of Ukraine [WRAU], 2024). Agricultural waste, comprising 70% of organic waste, could offset 5–7% of national fertilizer needs, saving €100 million yearly (Shevchenko et al., 2022).

Small-scale biogas and composting facilities currently employ 500–1,000 workers directly, with potential expansion to 10,000 jobs by 2030 through rural cooperatives (Pryshliak, 2021; Kolodiichuk et al., 2021). Ukraine's 2022 Law on Waste Management introduces extended producer responsibility, incentivizing private investment and potentially creating 5,000 indirect jobs across logistics and processing sectors (Public-Private Partnership Agency [PPPA], 2023).

The EU model provides a strategic blueprint for Ukraine, where recycling rates remain approximately tenfold lower due to infrastructure deficits and disruptions caused by ongoing conflict (Euronews, 2023). Alignment with the EU-Ukraine Association Agreement sets targets of 15% recycling by 2023 and 50% by 2030, unlocking €500 million in EU grants for biogas infrastructure development (Ministry of Foreign Affairs of Ukraine, n.d.; Zero Waste Europe, 2025). The prospects for Ukraine on this way are:

- **Energy Independence**: Ukraine's biomass potential could produce 10% of its electricity, reducing import reliance by €300 million annually (Geletukha et al., 2022).
- **Circular Economy Integration**: EU-style source separation could recover 40 million tonnes of bio-waste yearly, generating €1 billion in bio-products (Boldyreva et al., 2021).
- **Cross-Border Collaboration:** Projects like Zero Waste Cities, linking Ukrainian municipalities with EU partners, forecast 20% efficiency gains by 2027 (Zero Waste Europe, 2025).

Of course, challenges for Ukraine persist, including certification costs and low public awareness, but mechanisms such as carbon credits could accelerate adoption (Gonta Agro, 2025). Eco-friendly organic waste processing offers substantial economic benefits—cost savings, job creation, and new revenue streams—while advancing environmental objectives. The EU's successful model demonstrates scalability, and Ukraine's ongoing reforms place it on a trajectory for rapid convergence.

Conclusions

This research confirms that environmentally friendlyorganic waste processing is pivotal to promoting sustainability, diversifying energy sources, and ensuring ecological security in both the European Union and Ukraine. The EU's comprehensive circular economy-based system effectively minimizes greenhouse gas emissions, optimizes resource utilization, and expands renewable energy production.

Ukraine presents significant opportunities grounded in abundant agricultural residues, food industry by-products, and biodegradable household waste. Wider adoption of European best practices – including composting, anaerobic digestion, and biogas or biomethane production – can provide Ukraine with concrete benefits such as decreased fossil fuel dependency, rural development stimulation, job creation, and increased bioenergy export revenues.

Beyond economic advantages, eco-friendly waste processing reduces environmental risks, safeguards soil and water quality, and supports climate adaptation efforts. The establishment of regional bioenergy clusters and deeper integration into EU strategies will accelerate Ukraine's progress toward a resource-efficient circular economy. Therefore, organic waste valorization should be considered not only an ecological imperative but also a strategic pathway for sustainable long-term growth.

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Conflict of interest

The authors state no conflict of interest.

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