CIRCULAR ECONOMY PRINCIPLES IN UZBEKISTAN'S AGRICULTURAL SECTOR: TRANSFORMING WASTE INTO COMPETITIVE ADVANTAGE

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Abstract. *This article examines the application of circular economy principles to Uzbekistan's agricultural sector, with particular emphasis on converting crop residues, livestock waste, and agri-processing by-products into secondary raw materials, bioenergy, and organic soil amendments. The conventional linear agricultural model — extract, produce, discard — generates substantial economic losses through inefficient resource flows and rising waste disposal costs. The article analyses the current volume and composition of agricultural waste in Uzbekistan, the operational scale of existing biogas, composting, and recycling enterprises, the pipeline of planned waste-to-energy projects, and the competitiveness implications of circular agricultural models for farms, agri-processors, and rural communities. Data on annual crop residue tonnage, organic fertiliser substitution potential, biogas generation capacity, greenhouse gas abatement estimates, and circular economy investment flows are used to quantify the economic and environmental case for transition. The article argues that agricultural circularity is not merely an environmental obligation but a compelling economic strategy capable of reducing input costs, generating new revenue streams, and strengthening Uzbekistan's agri-food export proposition.*

Keywords: *circular economy, agricultural waste, biogas, composting, organic fertiliser, waste-to-energy, agri-circularity, resource efficiency, Uzbekistan.*

Introduction. The global agricultural system discards an estimated one-third of all food produced for human consumption — approximately 1.3 billion tonnes annually — along with vastly larger quantities of non-food biomass: straw, husks, stalks, pruning waste, manure, and agri-processing effluents [1]. This linear throughput model imposes mounting costs on producers, communities, and the environment alike, driving soil carbon depletion, water body eutrophication, methane emissions from decomposing organic matter, and unnecessary expenditure on synthetic inputs that could be partially substituted by regenerated organic nutrients.

For Uzbekistan, these dynamics are acutely relevant. Agriculture remains the dominant land use across an estimated 4.3 million hectares of irrigated territory and generates substantial volumes of biomass by-products annually — cotton stalks, rice husks, wheat straw, grape pomace, apricot stones, and livestock manure among the most volumetrically significant [1]. At the current low rate of formal recycling and valorisation, these materials represent both an environmental liability and a substantial untapped economic resource.

The circular economy framework — which replaces the linear model with closed nutrient, energy, and material loops — offers a rigorous theoretical and operational structure for capturing this latent value. This article investigates the scale of the opportunity, documents existing circular initiatives, analyses competitiveness implications, and proposes a policy roadmap for accelerating agri-circular transition in Uzbekistan.

Literature Review. The circular economy in agriculture is defined as a model that designs out waste and pollution, keeps products and materials in use, and regenerates natural systems within agri-food value chains. Its foundational principles, as articulated by the Ellen MacArthur Foundation (2019) and refined for food systems by Jurgilevich et al. (2016), include:

- Cascading biomass use: allocating agri-biomass first to the highest-value application before downstream energy recovery
- Closing nutrient loops: returning nitrogen, phosphorus, and potassium contained in organic wastes to agricultural soils, reducing dependence on mineral fertilisers
- Renewable energy generation from agricultural residues through anaerobic digestion, combustion, or pyrolysis
- Industrial symbiosis: linking farms with agri-processors, food manufacturers, and energy utilities in mutually beneficial waste-exchange networks
- Product redesign to reduce packaging waste and facilitate compostable or recyclable material flows across the agri-food chain

Empirical research by Cong et al. (2021) demonstrates that integrated biogas-digestate systems combining energy recovery with organic fertiliser production can reduce farm energy costs by 25–40 percent and synthetic fertiliser expenditure by 30–50 percent simultaneously. Research specific to Central Asia remains limited, though FAO (2022) has documented successful biogas cluster models in Kazakhstan and Kyrgyzstan that offer transferable design lessons for Uzbekistan.

Current State of Agricultural Waste Generation and Management in Uzbekistan. Uzbekistan generates substantial volumes of agricultural and agri-processing waste annually. Based on Ministry of Ecology data for 2024, the primary waste streams and their circular economy potential are as follows [5]:

Waste Stream	Annual Volume	Current Utilisation Rate (%)	Circular Potential

Cotton stalks (guzapoya)	2.1 million tonnes	18	Biogas, particle board, compost
Wheat and barley straw	3.8 million tonnes	31	Cattle feed, compost, bioenergy
Rice husks	420,000 tonnes	12	Silica extraction, fuel pellets
Grape and fruit pomace	280,000 tonnes	9	Distillation, biogas, compost
Livestock manure	24 million tonnes	22	Biogas, organic fertiliser
Agri-processing effluents	1.6 million tonnes	5	Anaerobic treatment, irrigation

Table 3: Agricultural waste streams and circular economy potential, Uzbekistan, 2024 [1, 5].

The low utilisation rates across most waste streams — ranging from 5 percent for agri-processing effluents to 31 percent for cereal straw — confirm that the majority of potentially valuable biomass is currently disposed of through open-field burning, unmanaged dumping, or under-optimised landfill, generating unnecessary greenhouse gas emissions and forgoing significant economic value.

Circular Economy as a Factor of Agricultural Competitiveness. Circular economy principles enhance agricultural competitiveness through cost reduction, new revenue creation, market differentiation, and regulatory compliance.

On the cost reduction side, substituting biogas-derived energy for purchased electricity or diesel can reduce farm energy bills by 20–35 percent in livestock-intensive operations. Replacing 30 percent of synthetic nitrogen fertiliser with anaerobic digestate — which delivers nitrogen in a plant-available ammonium form — would save an average irrigated grain farm approximately USD 180 per hectare annually at current fertiliser prices [2].

New revenue streams emerge when formerly discarded by-products are valorised. Cotton stalk biochar — produced by pyrolysis at temperatures of 400–600°C — commands prices of USD 120–180 per tonne in international markets as a soil amendment and carbon sequestration product. Grape pomace pressed from Uzbekistan's growing wine and raisin industry can be processed into tartaric acid, valued at USD 4–6 per kilogram, and grape seed oil, commanding USD 8–12 per litre in speciality food markets [5].

Market differentiation benefits arise because circular agricultural practices — documented through traceability systems — increasingly meet the prerequisites for premium sustainability certifications such as Rainforest Alliance, GlobalG.A.P., and EU Organic, opening higher-value market segments. European and Gulf Cooperation Council buyers in particular are beginning to incorporate supply chain circularity metrics into their procurement scorecards.

Waste-to-Energy and Biogas Development Pipeline. Uzbekistan's waste-to-energy and biogas pipeline represents a significant component of the national circular economy agenda. According to Ministry of Ecology data, several projects currently under development are expected to collectively process 4.7 million tonnes of organic waste per year, generate 2.1 billion kWh of electricity, save 152 million

cubic metres of natural gas annually, prevent 2.4 million tonnes of greenhouse gas emissions, and create 1,200 new skilled jobs [5]. These projects are planned for implementation across eleven regions between 2025 and 2027.

In the biogas subsector, the government has approved construction of 48 centralised biogas plants serving livestock clusters in the Fergana Valley, Surkhandarya, and Khorezm regions, with a combined installed capacity of 38 MW. Each plant is designed to process manure from 5,000–8,000 head of cattle or equivalent, producing biogas for electricity generation and digestate for organic fertiliser production. At full capacity, the 48 plants would supply organic fertiliser to approximately 96,000 hectares of arable land annually, reducing mineral fertiliser imports by an estimated USD 42 million per year [2].

Competitiveness Implications for Farms and Agri-processors. For individual farms and agri-processors, adopting circular economy practices generates a layered set of competitiveness advantages. Input cost savings from on-farm biogas and compost production improve profit margins and reduce exposure to volatile international commodity prices for fertilisers and energy. New by-product revenue streams diversify income, reducing dependence on single commodity prices and improving financial resilience. Access to premium sustainability-certified markets increases revenue per unit of output, offsetting any capital investment required for circular infrastructure.

Clustering effects further amplify individual benefits. Farms participating in shared biogas and composting clusters in the Namangan and Fergana regions have reported aggregate input cost savings of USD 210–280 per hectare — 15–22 percent of total production cost — alongside a 28 percent reduction in synthetic fertiliser procurement, based on monitoring data collected by the Entrepreneurship Development Fund in 2024 [4].

Conclusion. The circular economy presents Uzbekistan's agricultural sector with a compelling and empirically grounded pathway toward simultaneously improving environmental performance, reducing operating costs, creating new revenue streams, and strengthening export competitiveness. The current low utilisation rates of the country's major agricultural waste streams — ranging from 5 to 31 percent — indicate that the vast majority of potential circular value remains uncaptured [1, 5].

The national pipeline of waste-to-energy, biogas, and organic fertiliser projects — capable of processing 4.7 million tonnes of waste annually and generating 2.1 billion kWh of electricity — signals strong institutional momentum, but accelerated private sector participation is required to close the investment gap [5]. Policy measures that can unlock this participation include: performance-based subsidy schemes for biogas plant construction; mandatory organic waste segregation regulations for agri-processors above defined size thresholds; development of a national biochar and digestate quality certification standard; and integration of circular economy criteria into agricultural loan eligibility assessments [2, 3, 4].

When systematically implemented, agri-circular strategies transform what was previously an environmental liability — crop residues, manure, processing effluents — into productive assets that strengthen farm balance sheets, reduce the national fertiliser import bill, and advance Uzbekistan's commitments to climate-smart, resource-efficient agricultural development.

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