

GLOBAL ECONOMIC INTEGRATION AS A CONTROL MECHANISM FOR CIRCULAR BIOECONOMY TRANSITION: ENVIRONMENTAL ACCELERATION EVIDENCE FROM UZBEKISTAN

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Abstract

The article examined how global economic integration could support circular bioeconomy governance in Uzbekistan. Secondary data from international organisations and national sources were assessed through descriptive and comparative analysis. WTO accession, GSP+ preferences and enhanced partnership mechanisms were considered alongside environmental monitoring, accountability and technology transfer. Indicators of waste processing, biomass potential and trade integration were systematised. Integration milestones coincided with environmental reforms, although causality was not established. A conceptual model linked international cooperation, national institutions and environmental outcomes. Priorities were identified for harmonising statistics, developing regional infrastructure and using biomass efficiently. The findings clarified opportunities for international cooperation in circular bioeconomy governance.

Keywords: circular bioeconomy, global economic integration, environmental governance, international cooperation, environmental monitoring, technology transfer, waste recycling, biomass.

Annotatsiya

Maqolada global iqtisodiy integratsiyaning aylanma bioiqtisodiyotga o'tishdagi boshqaruv imkoniyatlari O'zbekiston misolida o'rganildi. Xalqaro tashkilotlar hisobotlari va milliy manbalardagi ikkilamchi ma'lumotlar tavsifiy hamda qiyosiy tahlil qilindi. Jahon savdo tashkilotiga a'zolik jarayoni, GSP+ preferensiyalari va kengaytirilgan sheriklik mexanizmlari ekologik monitoring, hisobdorlik va texnologiyalar transferi bilan bog'liq holda ko'rib chiqildi. Chiqindilarni qayta ishlash, biomassa salohiyati va savdo integratsiyasi ko'rsatkichlari tizimlashtirildi. Integratsiya bosqichlari bilan ekologik islohotlarning vaqt jihatidan uyg'unligi qayd etildi, biroq sababiy bog'liqlik tasdiqlanmadi. Xalqaro hamkorlik, milliy institutlar va ekologik natijalarni bog'lovchi konseptual model taklif etildi. Statistik hisobni muvofiqlashtirish, hududiy infratuzilmani rivojlantirish va biomassadan samarali foydalanish yo'nalishlari belgilandi. Natijalar aylanma bioiqtisodiyotni boshqarishda xalqaro hamkorlik imkoniyatlarini aniqlashtirishga xizmat qildi.

Kalit so'zlar: aylanma bioiqtisodiyot, global iqtisodiy integratsiya, ekologik boshqaruv, xalqaro hamkorlik, ekologik monitoring, texnologiyalar transferi, chiqindilarni qayta ishlash, biomassa.

Аннотация

В статье были изучены управленческие возможности глобальной экономической интеграции при переходе к циркулярной биоэкономике на

примере Узбекистана. Вторичные данные международных организаций и национальных источников были рассмотрены методами описательного и сравнительного анализа. Процесс вступления во Всемирную торговую организацию, предпочтения GSP+ и механизмы расширенного партнёрства были рассмотрены во взаимосвязи с экологическим мониторингом, подотчётностью и трансфером технологий. Были систематизированы показатели переработки отходов, потенциала биомассы и торговой интеграции. Было отмечено временное совпадение интеграционных этапов и экологических реформ без установления причинности. Была предложена концептуальная модель взаимодействия международного сотрудничества, национальных институтов и экологических результатов. Были определены направления согласования статистики, развития региональной инфраструктуры и использования биомассы для совершенствования управления циркулярной биоэкономикой.

Ключевые слова: циркулярная биоэкономика, глобальная экономическая интеграция, экологическое управление, международное сотрудничество, экологический мониторинг, трансфер технологий, переработка отходов, биомасса.

INTRODUCTION

The global economy currently draws more than 106 billion tonnes of materials annually, a volume that has grown from 79 billion tonnes in 2011 and is projected to keep rising unless resource use is structurally decoupled from economic growth [6]. Paradoxically, as material throughput has expanded, the share of that throughput supplied by secondary, recycled materials has fallen - from 9.1 percent in 2018 to 6.9 percent in 2025 - meaning the global economy has become less, not more, circular over the past seven years [6]; [31]. This divergence between rising consumption and declining circularity is occurring while material extraction and processing already account for an estimated 70 percent of global greenhouse gas emissions and over half of biodiversity loss [31], which places the circular bioeconomy - the substitution of fossil and virgin-material flows with renewable, biologically-based and recirculated resources - at the center of contemporary environmental governance debates.

Within advanced economies, the bioeconomy has already reached a scale that makes it a strategic policy lever rather than a niche sector. In the European Union alone, biomass-producing and biomass-converting activities employed 17.1 million people and generated 863 billion euros in value added in 2023, equivalent to 5 percent of EU GDP; when downstream services are included, the bioeconomy's estimated contribution rises to as much as 2.7 trillion euros, or 11-16 percent of GDP [11]; [12];. This scale did not emerge organically: it is the product of two decades of coordinated strategy revisions, monitoring systems, and - critically - external integration mechanisms that tie market access and cooperation to environmental performance.

Middle-income and transition economies face a different starting point. Uzbekistan illustrates this trajectory well. The country generated 14.8 million tonnes of household waste in 2024, of which only 6.1 percent was processed at specialized

enterprises [21], while satellite monitoring by the national space agency Uzbeekkosmos identified 1,928 unauthorized dumpsites covering roughly 721 hectares, against only 319 officially registered landfills [1]; [29]. At the same time, Uzbekistan is undergoing an unusually rapid period of global economic integration: it has held preferential GSP+ access to the EU market since 2021, concluded an Enhanced Partnership and Cooperation Agreement (EPCA) with the EU in October 2025, completed bilateral WTO market-access negotiations with the EU in the same month, signed a Bilateral Market Access Protocol with the EU in December 2025, and is targeting full WTO accession at the organization's 14th Ministerial Conference in 2026 [17]; [18]; [34]; [38]. In parallel, the government established a dedicated Agency for Waste Management and Circular Economy Development in September 2024 and declared 2025 the 'Year of Environmental Protection and Green Economy' [21]; [35].

The central research problem addressed in this paper is that, while the bioeconomy and circular-economy literatures increasingly treat global integration and environmental transition as parallel processes, the mechanism by which integration actually controls, disciplines, or accelerates circular bioeconomy adoption at the national level remains under-specified - particularly for transition economies. Existing scholarship on Uzbekistan's green transition documents domestic waste and energy indicators [3]; [36] or trade indicators [2]; [22] largely in isolation from one another. This study addresses that gap by (a) mapping the specific integration channels through which external actors monitor and condition Uzbekistan's environmental performance, (b) benchmarking Uzbekistan's circular bioeconomy indicators against global and EU reference values, and (c) proposing a conceptual framework in which global integration operates as a control loop linking external conditionality to domestic instruments and, ultimately, to accelerated environmental outcomes.

The remainder of the paper is organized as follows. Section 2 reviews the related literature. Section 3 describes the data sources and analytical approach. Section 4 presents the results across global, EU-benchmark, and Uzbekistan-specific indicators and discusses the findings in relation to the proposed control-loop framework and to the wider circular bioeconomy governance literature. Section 5 concludes with policy implications and directions for further research.

LITERATURE REVIEW

The circular economy has been conceptualized in many ways. Kirchherr et al. [27], analysing 114 definitions, found that most of them describe the circular economy as a combination of reduce, reuse and recycle activities, while far fewer explicitly link it to sustainable development. Geissdoerfer et al. [20] similarly present the circular economy as a new sustainability paradigm, but note that its relationship with broader sustainability goals remains conceptually unclear. The bioeconomy literature has developed in parallel. D'Amato et al. [8] compared the green, circular and bio economy concepts and showed that they share the aim of reconciling economic and environmental goals but differ in focus: the circular economy emphasizes resource efficiency, whereas the bioeconomy emphasizes the replacement of fossil resources with renewable biological ones. Stegmann et al. [33] combine these

ideas in the concept of the circular bioeconomy, in which biomass is used in cascades, residues are valorized, and materials are kept in productive cycles for as long as possible.

At the global level, monitoring data show that the transition remains slow. The Circularity Gap Reports [5; 6] and the UNEP-led global material-flow database [32] document continued growth in material extraction together with a declining share of secondary materials. In the European Union, the bioeconomy is tracked through a dedicated monitoring system maintained by the Joint Research Centre, whose assessments point to economic progress but weaker performance on sustainability and climate objectives [25]; [26].

A second strand of literature concerns the link between trade integration and the environment. Copeland and Taylor [7] distinguish scale, composition and technique effects through which trade can either raise or lower pollution, and show that the net outcome depends strongly on domestic policy. Frankel and Rose [15], controlling for the joint determination of income and trade, found no evidence that openness systematically harms the environment and some evidence that it improves several measures of air quality. Bradford [4] describes how the European Union exports its regulatory standards through access to its large internal market, a process known as the “Brussels effect”. This mechanism is directly relevant to preferential schemes such as GSP+, where access to the EU market is tied to the implementation of international conventions, including environmental ones [10]; [22].

For Uzbekistan, the domestic policy base for a green transition was set by the Strategy for the transition to a green economy for 2019-2030 [39]. Recent studies and reviews describe the country's waste-management and energy indicators [3]; [24]; [36] and investment-policy priorities [30], while analyses of trade integration focus on WTO accession and regional cooperation [2]; [22]. However, these strands are rarely connected. The literature therefore leaves open the question of how external integration mechanisms translate into circular bioeconomy outcomes in a transition economy. This study addresses this gap by treating global integration as a control mechanism and examining this idea against Uzbekistan's recent indicators.

METHODOLOGY

Research design

This study follows a descriptive-comparative research design based entirely on secondary data drawn from institutional, statistical, and peer-reviewed sources published between 2023 and 2026. No primary survey or interview data were collected. The design combines (a) a global-level review of circularity and material-flow indicators, (b) a regional benchmark drawn from the European Union's bioeconomy monitoring system, and (c) a national case study of Uzbekistan's waste-management, biomass-energy, and trade-integration indicators. This triangulated structure allows Uzbekistan's circular bioeconomy performance to be interpreted against both a global baseline and a regional frontier case.

Data sources

Global material-flow and circularity data were obtained from the Circularity Gap Report 2025 [6], the UNEP-led Global Material Flows Database and associated 2024 update published in the Journal of Industrial Ecology [32], and the United Nations Sustainable Development Goals indicator reports [37]. European Union bioeconomy benchmark data were obtained from the Joint Research Centre's 2025 report 'The EU bioeconomy at a glance' [26], the European Commission's 2025 EU Bioeconomy Strategy factsheet [11], and the EU Bioeconomy Monitoring System [28]. Uzbekistan-specific data were obtained from the Ministry of Ecology, Environmental Protection and Climate Change and the Government portal gov.uz [21], Gazeta.uz reporting on official statements [17]; [18]; [19], an Asian Development Bank (ADB) infrastructure assessment and brief [1], satellite-monitoring data from the national space agency Uzbeekkosmos [29], the UNECE Fourth Environmental Performance Review of Uzbekistan [36], the International Energy Agency's Uzbekistan Energy Profile [24], an OECD investment-policy roadmap [30], and a peer-reviewed regional case study [3].

Analytical framework and indicators

Indicators were grouped into five analytical categories: (i) global material-flow and circularity indicators (material consumption, circularity rate, material footprint); (ii) bioeconomy scale indicators (employment, value added, R&D intensity); (iii) national waste-management indicators (generation, processing rate, landfill count); (iv) global-integration indicators (trade volumes, preferential-access milestones, accession timeline); and (v) biomass and renewable-energy potential indicators. These five categories were then organized into a conceptual control-loop framework (presented in Section 4.6) that links external integration channels to domestic circular bioeconomy instruments and to environmental outcomes, allowing the empirical indicators to be read as evidence for each stage of the loop rather than as disconnected statistics.

ANALYSIS AND RESULTS

Global material consumption rose from 79 billion tonnes in 2011 to more than 106 billion tonnes in 2025, surpassing the 100-billion-tonne threshold for the first time in the report's history [6]. Over the same broad period, the global circularity metric - the share of material inputs supplied by secondary (recycled or reused) sources - declined from 9.1 percent in 2018 to 7.2 percent in the 2024 edition of the report [5] and to 6.9 percent in the 2025 edition, a drop of more than two percentage points in seven years [6]; [16]. Table 1 summarizes these global indicators.

Table 1

Global Material Flow and Circularity Indicators, 2011-2025¹

Indicator	Value	Year	Source
Global material consumption	79 billion tonnes	2011	[6]
Global material consumption	106 billion tonnes	2025	[6]
Global circularity rate, %	9.1	2018	[6]
Global circularity rate, %	7.2	2023/24	[5]
Global circularity rate, %	6.9	2025	[6]

¹ Source: compiled by the author from Circle Economy & Deloitte [5; 6] and Reconomy [31].

Indicator	Value	Year	Source
Share of global GHG emissions linked to material use, %	70	2021	[31]
Share of global biodiversity loss linked to resource extraction, %	>50	2020	[31]

Table 1 shows two opposite trends. Material consumption grew from 79 to 106 billion tonnes between 2011 and 2025, while the global circularity rate fell from 9.1% to 6.9% between 2018 and 2025. The last two rows explain why this matters: material use is linked to about 70% of global greenhouse gas emissions and to more than half of biodiversity loss [31]. The decline of the circularity rate is presented in Figure 1.

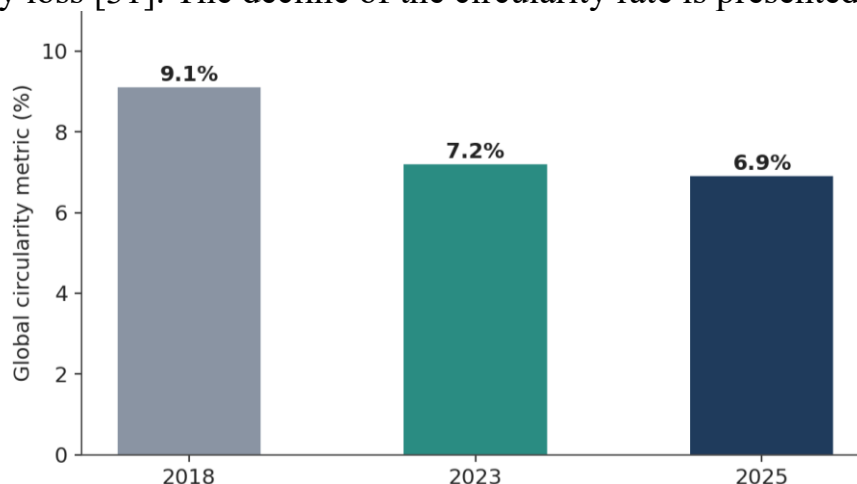


Figure 1. Decline of the Global Circularity Rate, 2018-2025¹

Figure 1 shows that the global circularity rate fell at each reporting point: 9.1% in 2018, 7.2% in 2023 and 6.9% in 2025 [5]; [6]. The decline was sharpest between 2018 and 2023 and has continued at a slower pace since then. The growth of material consumption over a comparable period is presented in Figure 2.

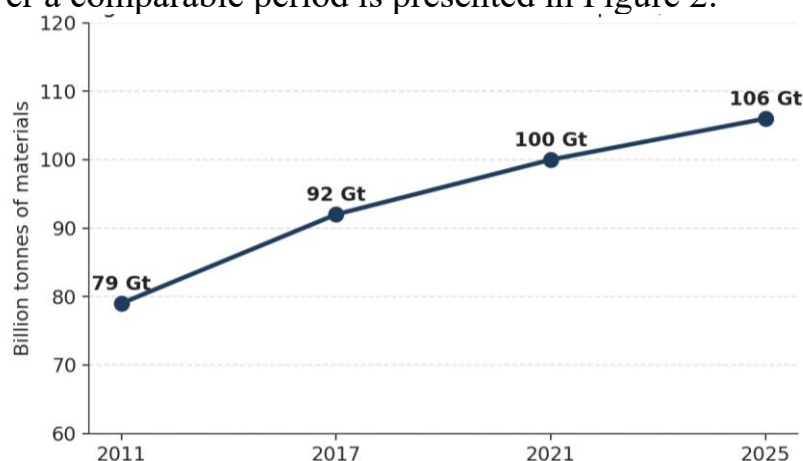


Figure 2. Growth of Global Material Consumption, 2011-2025²

¹ Source: Circle Economy & Deloitte, Circularity Gap Report 2024 and 2025 [5; 6].

² Source: Circle Economy & Deloitte, Circularity Gap Report 2025 [6].

Figure 2 shows that global material consumption rose from 79 billion tonnes in 2011 to 92 billion tonnes in 2017, 100 billion tonnes in 2021 and 106 billion tonnes in 2025 [6]. Read together with Figure 1, it confirms that the supply of recycled materials is not keeping pace with the growth of total material demand.

The regional distribution of this material burden is highly unequal. High-income countries consume roughly six times more materials per capita than lower-income countries, and richer nations' material footprint has remained broadly stable since the 2008-2009 financial crisis while footprints in Asia-Pacific, West Asia, and Africa have grown sharply since 2000 [32]. Within the European Union, the material footprint peaked at around 18 tonnes per capita in 2007/08, fell to about 14 tonnes per capita in 2013-2016 following the financial crisis, and stood at 13.7 tonnes per capita in 2024 - equivalent to approximately 6.2 billion tonnes for the bloc as a whole [13] (Figure 3).

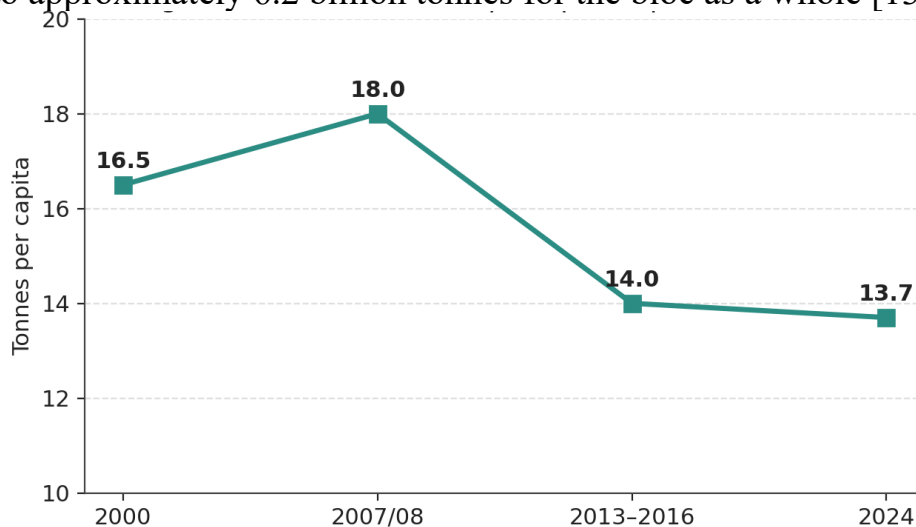


Figure 3. EU Material Footprint per Capita, 2000-2024¹

Figure 3 shows that the EU material footprint rose from 16.5 tonnes per capita in 2000 to a peak of 18.0 tonnes in 2007/08, then dropped to 14.0 tonnes in 2013-2016 and to 13.7 tonnes in 2024 [13]. This suggests that in a highly integrated and closely monitored economy, per capita resource use can be stabilized and gradually reduced.

The European Union's bioeconomy provides the clearest evidence that global integration and sustained monitoring can scale a circular bioeconomy over time. As shown in Table 2, biomass-producing and -converting sectors employed 17.1 million people (8 percent of EU jobs) and generated 863 billion euros in value added (5 percent of GDP) in 2023, while total bioeconomy-relevant activity - including services - reached an estimated 1.9-2.7 trillion euros, or 11-16 percent of GDP [11]; [26]. R&D investment in bioeconomy sectors reached 23.2 billion euros, and the European Commission estimates that every direct bioeconomy job supports 2.9 additional indirect jobs elsewhere in the EU economy [11].

¹ Source: Eurostat, Material flow accounts statistics - material footprints [13].

Table 2

EU Bioeconomy Key Performance Indicators, 2023-2025¹

Indicator	Value	Source
Jobs in biomass producing/converting sectors, million	17.1	[26]
Value added of biomass sectors, billion euros	863	[26]
Total bioeconomy value (incl. services), up to trillion euros	2.7	[11]
R&D investment in bioeconomy sectors, billion euros	23.2	[11]
Indirect job multiplier	2.9 jobs per 1 direct bioeconomy job	[11]
Global biotechnology sector growth, billion euros	over 720	[11]

Table 2 shows that the EU bioeconomy is a large economic sector: it employs 17.1 million people, generates 863 billion euros in value added and attracts 23.2 billion euros in R&D investment. The multiplier of 2.9 indirect jobs per direct job indicates that its effect extends well beyond the biomass sectors themselves [11]; [26].

This scale has been reached alongside - not instead of - external accountability structures: the number of countries worldwide with dedicated national bioeconomy strategies grew from 20 in 2015 to more than 60 in 2024, with 27 of those maintaining cross-sectoral strategies comparable to the EU model [14]; [23], suggesting that strategy adoption itself is diffusing through international benchmarking and summit-based cooperation such as the Global Bioeconomy Summit series (Figure 4).

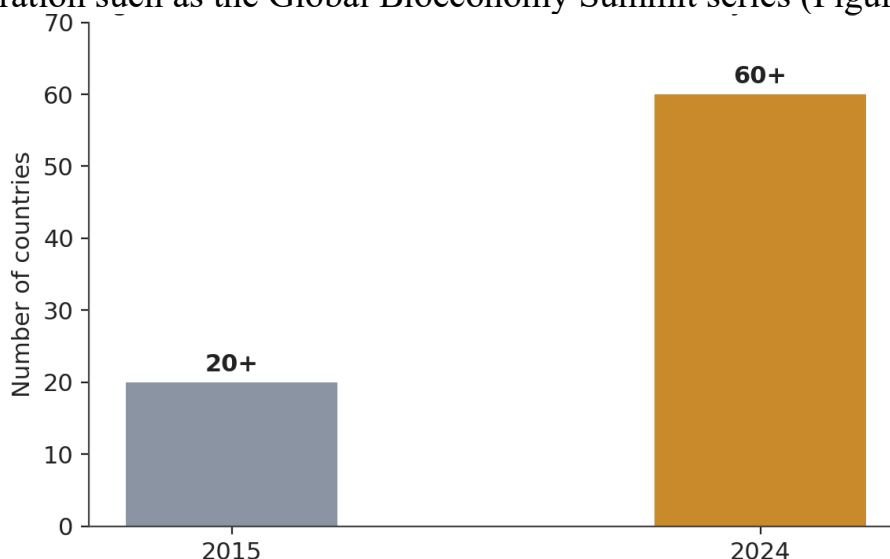


Figure 4. Countries with National Bioeconomy Strategies²

Figure 4 shows that the number of countries with national bioeconomy strategies tripled, from about 20 in 2015 to more than 60 in 2024 [14; 23]. This rapid spread

¹ Source: compiled by the author from JRC [26] and European Commission [11].

² Source: IACGB [23]; FAO, Global Webinar Series on Forest-Based Bioeconomy [14].

supports the view that international cooperation and benchmarking speed up the adoption of bioeconomy policies.

Against this global and EU backdrop, Uzbekistan's circular bioeconomy remains at an early institutional stage. In 2024, the country generated 14.8 million tonnes of household waste, of which just 900,500 tonnes (6.1 percent) were processed at 292 specialized enterprises [21]; this enterprise-level processing share is a narrower measure than the economy-wide municipal recycling rate, which the United Nations Economic Commission for Europe placed at 5.2 percent in 2024, alongside a finding that most of the country's roughly 200 registered landfill sites fail to meet modern environmental standards [36]. Municipal solid waste generation in Tashkent alone rose from approximately 1,950 tonnes per day in 2019 to nearly 3,000 tonnes per day in 2024 - an increase of more than 53 percent in five years, driven by urbanization and rising consumption [1]. Collection rates outside major cities remain low, at 50-60 percent, and while 319 landfill sites were officially registered as of 2024, satellite monitoring by Uzbekkosmos identified 1,928 unauthorized dumpsites covering approximately 721 hectares near roads, settlements, and farmland [1]; [29]. The discrepancy between the 319-site ADB figure and UNECE's approximately 200-site figure likely reflects differences in survey date and registration methodology between the two assessments and is noted here as a limitation of cross-source comparison (see Section 3.4). An estimated 128 million tonnes of industrial and hazardous waste has accumulated nationally, for which processing plans are only now being developed [19] (Table 3).

Table 3

Uzbekistan Waste Management Indicators, 2024¹

Indicator	Value	Source
Household waste generated, million tonnes (2024)	14.8	[21]
Waste processed at specialized enterprises, t	900,500	[21]
Official landfill sites (ADB survey, 2024)	319	[1]
Registered landfill sites (UNECE survey, 2024)	200	[36]
Unauthorized dumpsites (satellite-identified), hectares	1721	[29]; [1]
Accumulated industrial/hazardous waste, million tonnes	128	[19]
Tashkent municipal solid waste, 2019 → 2024, t/day	3,000	[1]
Municipal recycling rate (economy-wide), %	5.2	[36]

Table 3 summarizes the main waste indicators for Uzbekistan. Only 6.1% of household waste was processed at specialized enterprises and the economy-wide municipal recycling rate was 5.2%, while the number of unauthorized dumpsites (1,928) is about six times higher than the number of official

¹ Source: compiled by the author from Government of Uzbekistan [21], ADB [1], Kun.uz [29], Gazeta.uz [19] and UNECE [36].

landfills (319) [1]; [21]; [29]; [36]. The growth of waste generation in the capital is presented in Figure 5.

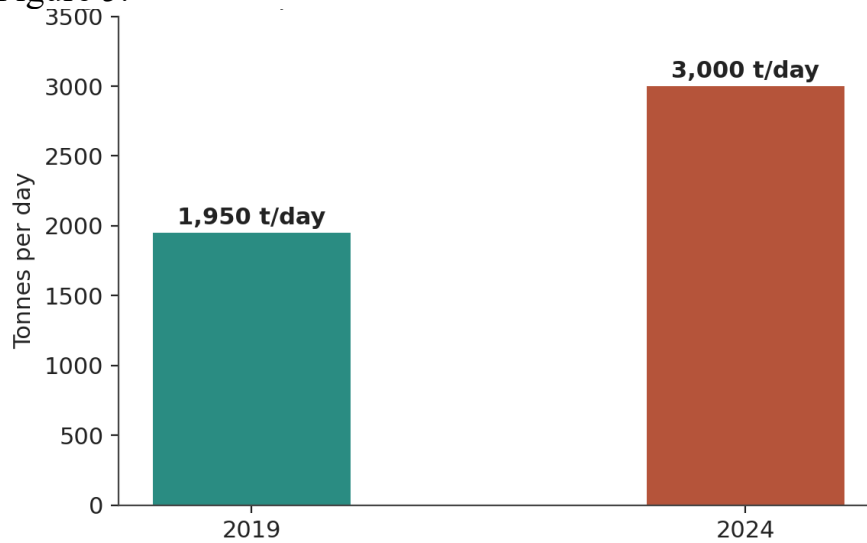


Figure 5. Municipal Solid Waste Generation in Tashkent, 2019-2024 (+53%)¹

Figure 5 shows that daily municipal solid waste generation in Tashkent increased from 1,950 tonnes in 2019 to about 3,000 tonnes in 2024, a rise of more than 53% [1]. This growth increases pressure on collection and landfill capacity in the capital. The national processing structure is shown in Figure 6.

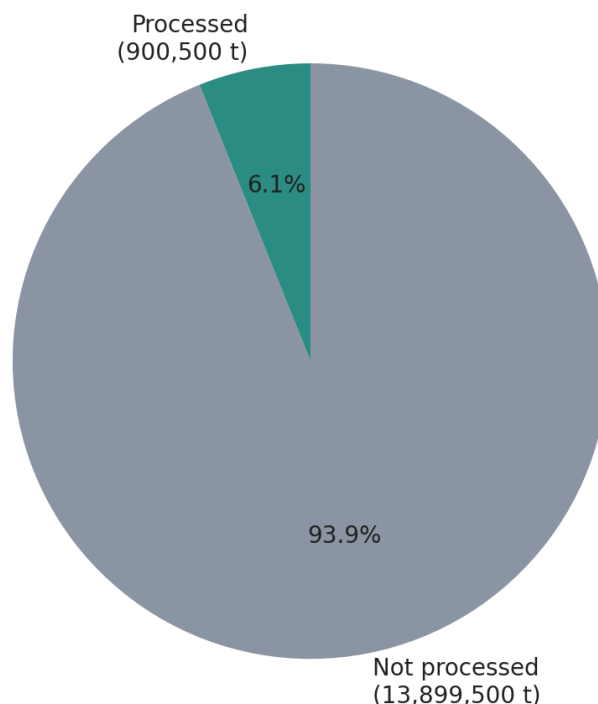


Figure 6. Uzbekistan Household Waste: Processed vs. Unprocessed, 2024²

¹ Source: Asian Development Bank, Sanitary Landfill Design and Future Pathways, ADB Brief No. 396 [1].

² Source: Government of Uzbekistan [21].

Figure 6 shows that of the 14.8 million tonnes of household waste generated in 2024, only 900,500 tonnes (6.1%) were processed, while 13,899,500 tonnes (93.9%) remained unprocessed [21]. This confirms that the waste system of Uzbekistan is still largely linear.

In response, the government created a dedicated Agency for Waste Management and Circular Economy Development in September 2024, has begun converting closed landfills into green spaces (47 reclaimed by December 2025), and has attracted foreign-financed waste-to-energy projects across ten regions expected to process 4.7 million tonnes of municipal waste annually and cut greenhouse-gas emissions by an estimated 2.4 million tonnes once operational between 2025 and 2027 [19; 35].

Uzbekistan's environmental-institutional reforms have proceeded in close temporal alignment with a rapid deepening of global economic integration (Table 4). The EU granted Uzbekistan GSP+ beneficiary status in April 2021, providing tariff-free access to more than 6,200 product lines conditional on implementing 27 international conventions covering human rights, labor, environmental protection, and good governance [10; 22]. GSP+-eligible exports to the EU rose from 93 million euros in 2019 to 450 million euros in 2022, saving Uzbek exporters more than 28 million euros in tariffs in that year alone [10].

Table 4

Uzbekistan's Global Integration Milestones, 2019-2026¹

Year	Milestone	Relevance to circular bioeconomy governance
2019-2030	Green Economy Transition Strategy adopted [39]	Domestic policy framework for circular/green transition
2021 (Apr.)	EU GSP+ status granted	Tariff-free access conditional on 27 conventions, incl. environmental
2022	EPCA negotiations concluded with EU	Deeper market access and non-tariff cooperation
2024 (Sep.)	Agency for Waste Management and Circular Economy Development established	Domestic institutional control mechanism
2025 (Oct.)	EPCA signed; EU-Uzbekistan WTO market-access talks concluded	Consolidation of rules-based integration
2025 (Dec.)	Bilateral Market Access Protocol with EU signed	Key WTO accession milestone
2026 (target)	WTO accession at 14th Ministerial Conference	Full multilateral rules-based integration

Table 4 shows that most integration milestones are concentrated in 2021-2026, the same period in which the national waste and circular economy institutions were created. The change in EU-Uzbekistan trade over this period is shown in Figure 7.

¹ Source: compiled by the author from Gazeta.uz [17; 18], The Diplomat [34], WTO [38], EU Delegation to Uzbekistan [10] and Resolution No. PQ-4477 [39].

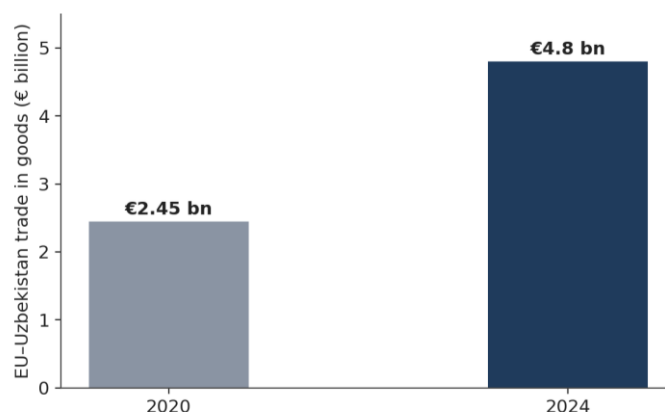


Figure 7. EU-Uzbekistan Trade Growth under GSP+, 2020-2024¹

Figure 7 shows that EU-Uzbekistan trade in goods grew from 2.45 billion euros in 2020 to 4.8 billion euros in 2024, almost doubling in four years [17]. The growth of exports eligible for GSP+ preferences is presented in Figure 8.

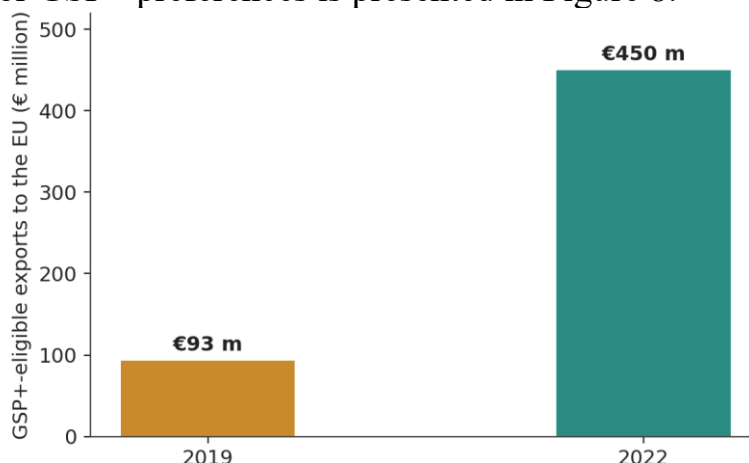


Figure 8. Growth of Uzbekistan's GSP+-Eligible Exports to the EU²

Figure 8 shows that Uzbekistan's GSP+-eligible exports to the EU increased from 93 million euros in 2019 to 450 million euros in 2022, nearly a fivefold rise [10]. This indicates that preferential access, together with the conditions attached to it, has become economically significant for Uzbek exporters.

By 2024, overall EU-Uzbekistan trade in goods reached nearly 4.8 billion euros, almost double the 2020 level, making the EU Uzbekistan's third-largest trading partner (10.4 percent of total trade) and second-largest export destination (7.2 percent of exports) [17]. Uzbekistan completed bilateral WTO market-access negotiations with 33 of 34 engaged WTO members by late 2025, including the EU, China, the United Kingdom, Switzerland, Canada, and Australia, and is targeting accession in 2026 after a 31-year process [18; 34]. Regional integration through the Eurasian Economic Union (EAEU) remains significant in parallel, accounting for roughly 24-26 percent of Uzbekistan's merchandise trade [2].

¹ Source: Gazeta.uz [17], citing European Commission trade data.

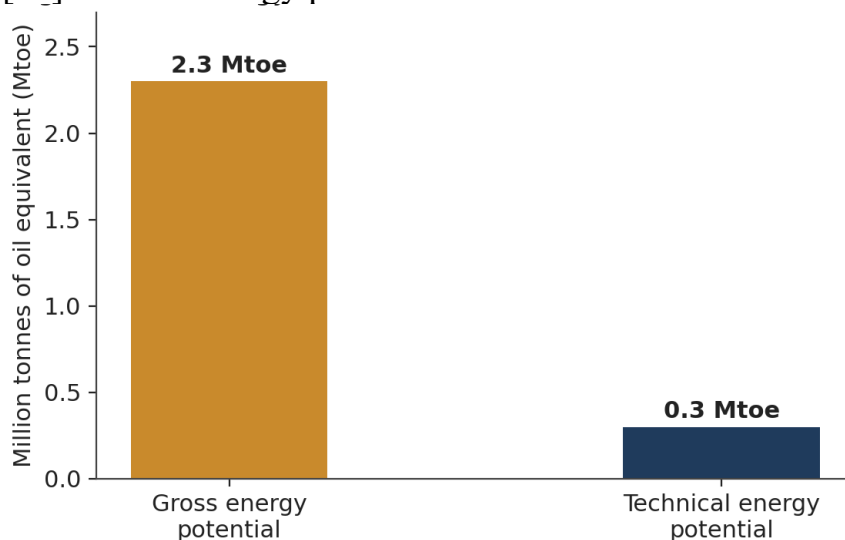
² Source: EU Delegation to Uzbekistan [10].

As the world's sixth-largest cotton producer, Uzbekistan generates substantial lignocellulosic agricultural residue with latent bioenergy value. Cotton-plant stalks alone represent a gross energy potential of 2.3 million tonnes of oil equivalent (Mtoe) annually, of which roughly 0.3 Mtoe is technically recoverable using current thermochemical conversion technology; total cotton cellulose waste reaches up to 10 million tonnes per year, most of which is still burned informally as rural cooking fuel rather than processed industrially [9; 24]. Reeds growing along irrigation canals add a further 10-12 million tonnes of biomass per year with largely untapped energy potential [24]. Table 5 and Figure 9 summarize these resources alongside Uzbekistan's much larger solar potential, which provides useful context for prioritizing investment.

Table 5
Uzbekistan's Renewable and Biomass Energy Potential¹

Resource	Gross potential	Technical potential	Source
Solar energy	$2,134 \times 10^3$ PJ	7,411 PJ	[24]; [30]
Cotton-plant stalks, Mtoe/year	2.3	0.3	[24]
Reeds (canal/waterway vegetation), million t/year	10-12	-	[24]
Total cotton cellulose waste, million t/year	up to 10	mostly used as informal fuel	[9]

Table 5 shows that Uzbekistan's biomass resources are considerable: cotton stalks alone have a gross potential of 2.3 Mtoe per year, and canal reeds add 10-12 million tonnes of biomass annually. At the same time, the technical potential of cotton stalks is only 0.3 Mtoe per year, while solar energy has a far larger technical potential of 7,411 PJ [24];[30]. The bioenergy potential of cotton stalks is shown in Figure 9.


Figure 9. Bioenergy Potential of Cotton-Plant Stalks in Uzbekistan²

¹ Source: compiled by the author from IEA [24], OECD [30] and EBSCO Research Starters [9].

² Source: International Energy Agency, Uzbekistan Energy Profile [24].

The gap between gross and technical potential - roughly an eightfold reduction for cotton stalks - illustrates a recurring theme in the results: Uzbekistan's raw circular bioeconomy endowment is substantial, but conversion into usable, monitored, and internationally verifiable output remains limited by processing infrastructure and technical capacity, precisely the constraint that integration-linked technology transfer and conditionality are positioned to address.

Figure 10 synthesizes the results into a conceptual framework describing how global integration channels function as a control loop for circular bioeconomy transition. Four external channels - WTO accession and trade rules, EU GSP+/EPCA conditionality, regional cooperation (EAEU, CIS, Central Asia), and global bioeconomy fora and standards - feed into a shared control loop built on reporting obligations, conditionality, benchmarking, and technology transfer. This loop, in turn, shapes two categories of domestic instruments: overarching circular bioeconomy institutions (the Green Economy Strategy, the Waste Management and Circular Economy Development Agency) and sector-specific actions (biomass energy, waste-to-resource investment, eco-industrial zones, extended producer responsibility). Both feed into the accelerated environmental outcomes documented in Sections 4.3-4.5: landfill reclamation, waste-to-energy capacity additions, and institutional reform occurring on a compressed multi-year timescale that coincides closely with Uzbekistan's 2021-2026 integration milestones.

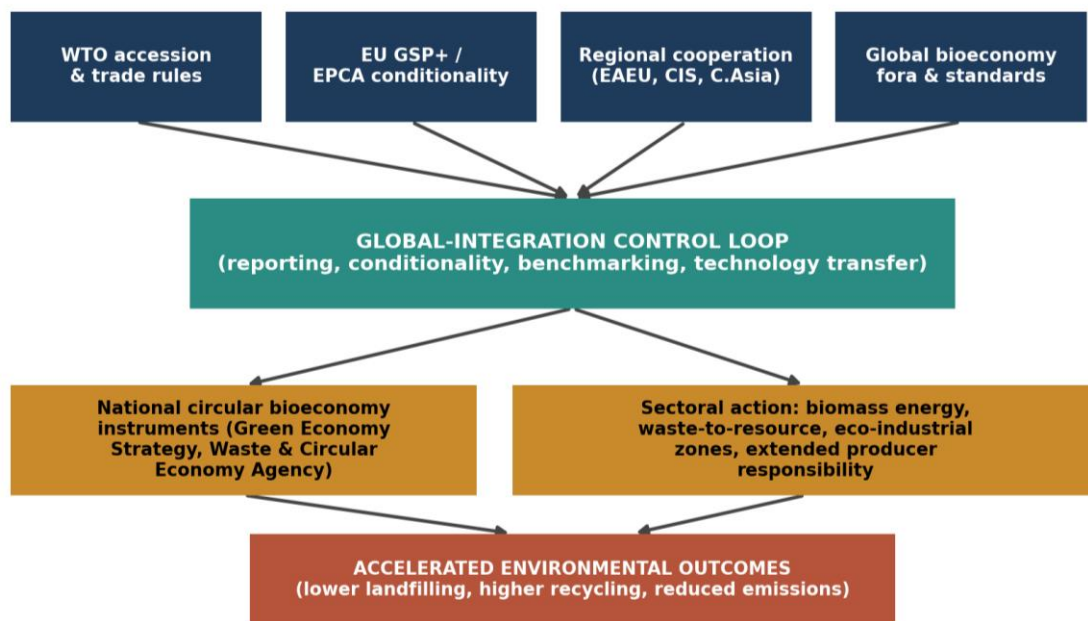


Figure 10. Conceptual Framework: Global Integration as a Control Mechanism for Circular Bioeconomy Transition and Environmental Acceleration¹

Figure 10 presents the logic of the framework from top to bottom: four external integration channels feed a single control loop, the loop shapes national institutions

¹ Source: developed by the author, synthesizing Sections 4.1-4.5.

and sectoral actions, and these in turn produce accelerated environmental outcomes. The framework is used below to interpret the results.

The results support the paper's central proposition: global integration functions primarily as an accountability and control structure rather than as a direct capital-transfer mechanism. GSP+ status did not itself fund Uzbekistan's waste infrastructure; rather, its conditionality - tied to 27 international conventions - created a recurring compliance obligation that domestic institutions had to satisfy to retain preferential access [10; 22]. Similarly, WTO accession negotiations function as a structured external audit of trade-relevant regulation, including technical barriers to trade and competition policy, that indirectly disciplines environmental and industrial governance even where circular economy rules are not the explicit subject of negotiation [38]. This interpretation is consistent with the EU's own bioeconomy trajectory, where monitoring systems such as the EU Bioeconomy Monitoring System have operated continuously since well before the bioeconomy reached its current 2.7 trillion euros scale [28], suggesting that sustained external and internal monitoring, more than any single funding instrument, is what allows a circular bioeconomy to compound over time.

Despite this acceleration, the scale gap between Uzbekistan and both the global and EU benchmarks remains substantial. Uzbekistan's economy-wide municipal recycling rate of 5.2 percent in 2024 [36] sits close to the declining global circularity metric of 6.9 percent [6], but this proximity is coincidental rather than structural: the global figure reflects secondary-material substitution across all material categories in mature, high-throughput economies, while Uzbekistan's figure reflects a much smaller, largely linear waste system still building basic sorting and processing infrastructure. The unauthorized-dumpsite ratio - roughly six unregistered sites for every one officially recorded landfill [1; 29] - indicates that measurement and monitoring capacity itself, not merely treatment capacity, is a binding constraint, reinforcing the argument that externally imposed reporting requirements under GSP+ and prospective WTO obligations can add real value by forcing systematic data collection.

Three risks temper an otherwise favorable reading of integration-driven acceleration. First, conditionality fatigue is a documented concern in the WTO-accession literature, where three decades of intermittent negotiation left some domestic industries 'skeptical about the benefits of WTO membership' after losing long-standing protections [34], suggesting that control mechanisms can generate political resistance that slows implementation even as formal commitments accumulate. Second, institutional capacity remains uneven: while Tashkent has begun large-scale waste-to-energy investment, collection rates outside major cities remain at 50-60 percent [1], meaning integration-linked reforms risk concentrating benefits geographically. Third, the global evidence that high-income countries' material footprints already exceed their domestic extraction by relying on imported primary materials [32] raises a legitimate concern that deeper integration into global value chains could, without careful sequencing, shift environmental burdens toward Uzbekistan rather than reduce them,

particularly if biomass or mineral exports expand faster than domestic circular processing capacity.

Because this study is observational and cross-sectional in structure, it documents temporal coincidence between Uzbekistan's integration milestones (2021-2026) and its environmental-institutional reforms rather than establishing statistical causality. Future research should apply panel or difference-in-differences designs across multiple GSP+ or WTO-accession countries to isolate the marginal effect of conditionality from concurrent domestic political will, and should incorporate primary survey data from Uzbekistan's newly created Waste Management and Circular Economy Development Agency once multi-year performance data become available.

CONCLUSION AND SUGGESTIONS

This study set out to examine how global economic integration functions as a control mechanism for circular bioeconomy transition, using Uzbekistan as an empirical case within a global and EU comparative frame. The evidence indicates that global integration operates less as a source of new capital and more as an external accountability structure - combining conditionality, reporting obligations, benchmarking, and technology transfer - that compresses the time otherwise required for domestic institutional and behavioral change. Uzbekistan's near-simultaneous progress on GSP+ retention, EPCA implementation, and WTO accession alongside the creation of a dedicated circular economy agency, large-scale waste-to-energy investment, and landfill reclamation supports this interpretation, even though the country's underlying circular bioeconomy indicators - a 5.2 percent municipal recycling rate and a largely untapped biomass-energy resource base of at least 2.3 Mtoe from cotton residues alone - remain well below global and EU benchmarks. For policymakers, the practical implication is that securing and maintaining integration frameworks should be treated as a governance tool in its own right, not only a trade-policy objective: each conditionality clause and reporting requirement can be leveraged deliberately to build the domestic monitoring capacity that Uzbekistan's circular bioeconomy transition currently lacks. For the research community, the proposed control-loop framework offers a starting point for comparative studies of other transition economies pursuing simultaneous trade integration and circular bioeconomy reform.

Based on the findings of the study, the following recommendations are proposed:

1. Use the reporting obligations under GSP+, the EPCA and future WTO membership as a tool for building a national system of waste and circularity statistics, including regular satellite monitoring of unauthorized dumpsites.

2. Reconcile the landfill data of different assessments (319 sites in the ADB survey and about 200 sites in the UNECE review) and publish a single national register of landfills.

3. Expand waste collection and sorting outside major cities, where collection rates remain at 50-60 percent, so that the benefits of integration-linked reforms are spread evenly across regions.

4. Develop technology-transfer projects with the EU and other partners to convert cotton-stalk and reed biomass into energy and bio-based products, with the aim of narrowing the gap between gross and technical potential.

5. Sequence deeper integration into global value chains with the growth of domestic circular processing capacity, so that the expansion of biomass and mineral exports does not shift environmental burdens to Uzbekistan.

6. Equip the Agency for Waste Management and Circular Economy Development with multi-year performance indicators that can later support comparative and causal studies of integration effects.

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