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From Waste Costs to Resource Value: Economic Incentives for Industrial Symbiosis in Uzbekistan

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Abstract. The circular-economy transition depends not only on recycling technologies but also on economically viable agreements that allow one enterprise to use another enterprise's residual materials. This article examines the transaction-cost, incentive and risk barriers to industrial symbiosis in Uzbekistan and proposes an enterprise-level resource-exchange mechanism for the AI Circular Ecosystem research initiative. The analysis combines the industrial-symbiosis literature, ISO guidance and Uzbekistan's waste-management and green-economy policy documents. A proposed net-exchange-surplus test considers avoided primary-material expenditure and disposal costs against processing, transport, testing and contracting expenditures. A clearly hypothetical example illustrates why material matching alone is insufficient for investment decisions. The paper recommends verified material passports, standardized resource-exchange agreements, transparent benefit-sharing rules, staged financial incentives and performance monitoring. Unlike national municipal-waste indicators, the proposed enterprise metrics would measure commercially feasible secondary-resource exchanges and their demonstrable effects. The article offers a policy-oriented conceptual contribution; no platform implementation or observed firm-level economic effects are claimed.

Keywords: circular economy; industrial symbiosis; secondary resources; transaction costs; economic incentives; resource-exchange agreements; Uzbekistan; AI Circular Ecosystem.

The linear production model treats extraction, manufacturing, consumption and disposal as separate stages. Consequently, a recoverable residue may appear as a compliance cost in one company's accounts even when the same material could substitute for a purchased input elsewhere. The circular economy changes this perspective by treating resource value as a characteristic of an entire value network rather than of an individual plant. The Global Resources Outlook 2024 warns that, without corrective policies, global resource extraction could be about

60% higher in 2060 than in 2020 [1]. Although global projections cannot be transferred directly to Uzbekistan, they demonstrate the importance of improving resource productivity alongside growth. Industrial symbiosis is a particularly relevant business mechanism. Chertow defines it in terms of mutually beneficial exchanges of materials, energy, water and by-products between otherwise separate enterprises, emphasizing geographical proximity and collaboration [2]. Subsequent research suggests that uncovering viable exchanges already embedded in regional production networks is often more productive than assuming that every industrial cluster can be designed from scratch [3]. Accordingly, the central question of this article is not simply how to identify waste streams, but how to make the transfer of technically usable residual resources financially attractive, legally compliant and contractually reliable. For Uzbekistan, this question relates to resource efficiency, industrial cost competitiveness and the modernization of waste management. It also motivates a distinct research application within the proposed AI Circular Ecosystem platform: the design of a decision-support and coordination service that assesses whether specific resource exchanges create measurable economic value. The analysis below is conceptual and policy-based. It presents neither field-survey findings nor tested platform outcomes.

A residual stream is not automatically a marketable secondary input. Its commercial use depends on composition, volume, contamination, timing, transportation distance and the receiving enterprise's technical requirements. A literature review of industrial-symbiosis platforms identifies information about material characteristics, flow quantities, location, prices, treatment costs, capacities and data-sharing arrangements as important inputs to finding workable matches [4]. Identifying two companies with apparently compatible materials is therefore only the beginning of a business decision. Three transaction-cost barriers arise. First, search costs increase when firms cannot discover the existence and quality of usable residual streams. Second, verification costs arise because receiving companies must establish chemical, mechanical or sanitary suitability rather than trust unverified catalogue descriptions. Third, coordination costs emerge from uneven delivery schedules, transport arrangements, payment terms and liability for rejected batches. Digital marketplaces can reduce search costs but cannot remove the need for testing, appropriate authorizations and enforceable agreements. Recent research on digital industrial-symbiosis platforms similarly highlights managerial commitment, trust and the need to assess economic and environmental outcomes together [5].

The present article proposes that each potential exchange be screened by a net exchange surplus (NES): the combined value of avoided primary-material purchases, recoverable-product value and avoided disposal expenses, less incremental preparation, processing, logistics, testing, compliance and contracting costs. Internal transfer payments between the participating firms redistribute this surplus but do not create additional value for the two-firm system as a whole. A transaction is economically defensible only where NES is positive under realistic price, quality and delivery assumptions, the receiving process remains compliant, and each party receives a sufficient share of benefits to participate. Distribution matters as much as aggregate surplus. Without a written rule for the price of the secondary input, investments in sorting and necessary quality checks may fall disproportionately on the supplying firm, while most savings accrue to the buyer. To overcome this problem, the proposed scheme uses a negotiable benefit-sharing corridor: the minimum acceptable payment covers the supplier's incremental recovery costs and outside option; the maximum acceptable payment reflects the buyer's avoided alternative procurement costs, after adaptation and delivery risks. Where these limits do not overlap, the arrangement should be redesigned or rejected rather than subsidized without justification.

Uzbekistan's Law "On Waste" of 5 April 2002, No. 362-II, establishes the statutory framework for waste management and identifies the reduction and rational use of waste among its objectives [8]. This matters for industrial symbiosis because a material's regulatory status and the responsibilities of its holder cannot be determined solely by a platform label. The Green Economy Transition Strategy for 2019–2030, approved by Presidential Resolution No. PP-4477 of 4 October 2019, provides a broader policy foundation for resource-efficient development [9]. Together, these

instruments support a transition toward resource conservation but do not, by themselves, prove that a particular enterprise-to-enterprise transfer is permitted or economically sound. A more recent framework is the updated “Uzbekistan–2030” Strategy approved under Presidential Decree No. PF-21 of 16 February 2026 [10]. Its published performance framework lists household-waste recycling at 5.3% for the 2025 baseline and targets of 5.5% in 2026 and 7% in 2030 [11]. These figures refer to municipal household-waste recycling; they must not be represented as the industrial secondary-resource utilization rate. This distinction is consequential: a new enterprise platform requires its own measurable baseline for industrial flows, recorded independently from national municipal-waste targets.

Institutional specialization is also increasing. Official government information describes the establishment and functions of a Waste Management and Circular Economy Development Agency, with organizational measures adopted in October 2025 [12]. The proposed platform should be considered a voluntary enterprise-support and research instrument, not a substitute for public waste registries or government regulatory functions. Data-sharing arrangements with competent authorities, if later needed, should depend on lawful authorization and explicit technical agreements, rather than on an assumed entitlement to access official databases.

The proposed economic mechanism contains four linked stages. At registration, an enterprise submits a structured resource passport recording origin, material category, quantity, time profile, handling restrictions, laboratory parameters and indicative price. At preliminary matching, the platform searches for technically plausible recipients using location, material compatibility and demand timing. At due diligence, each proposed transaction is checked for regulatory acceptability, quality verification, estimated net exchange surplus and allocation of commercial risks. At the agreement stage, participating firms confirm commercial terms and establish an auditable record of quantities delivered and accepted. Artificial intelligence would serve a limited and testable function: ranking promising exchanges, detecting unusual data entries and forecasting variable volumes from validated historical records. An AI match should never be treated as proof of chemical suitability or legal permission. ISO 59010:2024 gives business- and network-oriented guidance for transitioning value-creation models, while ISO 59020:2024 sets out principles for measuring circularity performance within defined system boundaries [6, 7]. The platform’s recommendation logic could draw on these concepts without claiming ISO certification or full compliance before independent assessment.

Table 1. Proposed instruments to reduce resource-exchange barriers

Barrier	Proposed instrument	economic	Verification and accountability
Information asymmetry	Structured material passports and standardized descriptions		Technical specifications, laboratory evidence and dated records
High transaction costs	Geographic matching and consolidated logistics planning		Transport quotes, accepted quantity and completed deliveries
Unequal benefits	Negotiated price corridor and benefit-sharing clauses		Signed contracts and both parties’ cost baselines
Quality and compliance risk	Conditional acceptance, sampling and traceable rejection rules		Independent tests where needed; responsibilities documented
Weak investment incentives	Time-limited pilot co-financing tied to actual performance		Verified avoided disposal and primary-input substitution

Consider a purely illustrative case involving 100 tonnes of manufacturing offcuts. After sorting and quality screening, only 70 tonnes are suitable for substitution in a second enterprise.

Assume, strictly for scenario analysis and not as observed Uzbek market data, that each suitable tonne could displace primary input worth UZS 1.6 million. The combined avoided input expenditure would be UZS 112 million. If diversion also avoids disposal spending of UZS 0.12 million per recovered tonne, the further benefit would be UZS 8.4 million. Suppose that incremental logistics, processing, tests and contracting together cost UZS 72 million. The net exchange surplus would then amount to UZS 48.4 million. This scenario does not establish real-world profitability. The result is sensitive to the recovered share, material specifications, the value of the displaced input and whether processing costs have been fully included. If suitability fell below expectations or the buyer required costly production-line adjustments, the benefit could disappear. Therefore, the platform should report an estimated value range and a break-even recovery level, not a single algorithmic profitability claim. It should also distinguish transfers among enterprises from genuine net material savings: counting the same recovered tonne more than once would overstate circularity performance.

A pilot assessment would compare matched transactions with feasible conventional alternatives and document three distinct outcomes: financial gains for each enterprise, the net material quantity replacing virgin inputs, and environmental indicators supported by appropriate emissions or life-cycle data. This discipline is necessary because a higher number of platform matches is an activity measure, not an economic or environmental result. First, prioritize sectoral pilots where large and regular residual streams meet recurring material demand. Agro-processing, textiles and construction-material production may offer candidate networks, but project partners must validate quantities, safety and market demand before choosing pilot sites. Geographic concentration is preferable initially because long-haul shipping can consume the value of low-price secondary materials. The first operating version should accept a narrow range of well-characterized streams rather than attempt to list every type of waste. Second, develop a standardized Circular Resource Exchange Agreement. The suggested agreement records the material passport reference, laboratory requirements, delivery calendar, sampling protocol, rejection and returns procedure, liability allocation, payment mechanism and handling of confidential production information. Such contractual standardization does not replace statutory permits. It can, however, lower bargaining costs and allow participants to compare commercial offers using consistent definitions. Third, design incentives around additional, verifiable activity instead of registrations. Any proposed public co-financing or concessional assistance should be considered only where authorized by the applicable budgetary and legal framework. Eligibility can be linked to previously unused streams, confirmed substitution of primary inputs, an audited minimum transaction volume and the absence of double-counted benefits. Incentives should be temporary, capped and evaluated against a counterfactual to reduce dependence on subsidies. Fourth, organize the data and governance model around firm confidentiality and independent verification. Commercial prices and recipes need not be exposed in full to every user. Firms should be able to publish a standardized material description while reserving sensitive test documentation for authorized counterparties. Conflicts of interest should be managed where a logistics provider or a recycler is also responsible for assessing the suitability of its own offer. A platform operator should preserve transaction audit trails without claiming to exercise the powers of a state inspector. Fifth, evaluate the project in sequential stages. A preparation phase should identify participating companies and baseline quantities. The transaction phase should validate actual matches, prices, acceptance rates and expenses. The evaluation phase should assess net surplus by firm, retained resource value, tonnes genuinely substituted and transaction failure rates. Claims about reduced imports, emissions or national productivity should be made only after evidence supports their attribution. This measured approach would make the AI Circular Ecosystem a defensible research instrument rather than merely a catalogue of potential recyclable materials.

The economic appraisal should not end when a supplier and recipient sign an agreement. For each completed exchange, the platform would record the offered mass, collected mass, independently accepted mass and mass actually incorporated in production. These categories are not interchangeable. The resource-circularity indicator for the pilot should therefore

use verified substituted material, not advertised listings or total deliveries. Consistent measurement boundaries are particularly important when a processor sells a recovered fraction to a manufacturer, because counting the processor's output and the manufacturer's consumption as two separate recovery events would exaggerate the performance of the network [7].

Economic additionality should be evaluated against a documented business-as-usual alternative. An exchange that already occurred before the platform's introduction can demonstrate service use but cannot be wholly attributed to the research intervention. Similarly, avoided disposal cost must be counted only for material that would otherwise have incurred that cost, and displaced primary-input purchases should be recorded at relevant comparable quality. The evaluation protocol should monitor both successful and unsuccessful transactions, including cases rejected for contamination, prohibitive logistics costs or inadequate commercial margins. These failed matches help explain whether the system provides useful recommendations rather than merely generating more activity. A defensible research design would select a defined industrial cluster, collect baseline data under confidentiality agreements, establish transparent eligibility criteria and follow transactions through at least one complete relevant production cycle. Results should be reported as descriptive pilot findings before causal effects are claimed. Where data permit, matched participating and nonparticipating firms could later be compared, accounting for differences in sector, output volumes and initial waste-handling practices. The ultimate test is whether firms retain higher resource value after all incremental costs and whether improvements remain commercially viable without permanent external support.

For Uzbekistan, the economic promise of industrial symbiosis rests on transforming residual materials from isolated disposal problems into contractual inputs within regional production networks. A digital platform can facilitate this change only if it lowers information and coordination costs, supports technically justified decisions and offers incentives that are acceptable to both suppliers and users of secondary resources. The proposed net exchange surplus, price-negotiation corridor, material passport and standard agreement provide a practical economic structure for the AI Circular Ecosystem initiative. The policy analysis also demonstrates why household-waste strategy targets should be distinguished from enterprise-level circularity performance. The proposed indicators must therefore be constructed from verified industrial material flows and documented business transactions. The main limitation of this article is the absence of pilot data. The next research stage should test the mechanism with participating enterprises and assess whether its predicted financial and environmental advantages persist after quality-control, logistics and compliance costs are included.

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