

Turning Waste into Wealth

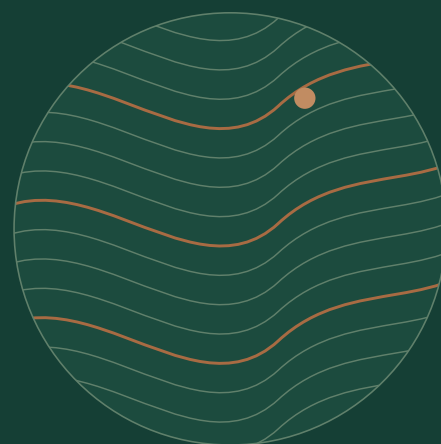
A strategy for critical mineral recovery from tailings in Uzbekistan

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A staged national programme to identify viable recovery projects, strengthen domestic processing capability and reduce environmental harm.

About this paper

The original study was prepared as part of the professional education programme at the Goldman School of Public Policy and submitted in partial fulfilment of the requirements for the Master of Public Affairs degree. This revised edition develops the policy recommendations using additional public sources.

The judgments and conclusions are solely those of the author and are not necessarily endorsed by the Goldman School, the University of California, or any other institution.

Contents

The paper moves from the policy opportunity and evidence base to project selection, public instruments and a bounded first-year programme.

Executive summary	3
1 The policy opportunity	4
2 Evidence and the domestic opportunity	5
3 International lessons and their limits	6
4 Select projects through decision gates	7
5 The five-pillar strategy	8
6 Institutions and implementation incentives	10
7 Compare the policy choices	11
8 Implementation and public spending	12
The assessment budget and its assumptions	13
9 Outcomes and conditions for success	14
Appendix A An illustrative economic test	15
Sensitivity and investment requirements	16
References	17

How to read the proposal

For the immediate funding decision, read the executive summary and Section 8. For project selection, read Sections 4 and 7. Appendix A explains the economic arithmetic and the additional evidence needed before investment.

Scope

This is a desk-based policy analysis, not a mineral resource statement or feasibility study. Budgets, institutional assignments and implementation dates are proposals. Numerical project examples are hypothetical.

Funding and competing interests

This paper received no external funding. The author is Founder and Executive Director of nElement.ai and reports no other relevant financial interests or commercial relationships in connection with this paper.

Executive summary

Uzbekistan should authorise a focused assessment programme before committing substantial public finance to mineral recovery from tailings. Recovery should proceed where a qualified product, credible economics and safer long-term site conditions can be demonstrated.

The country has a practical starting point: industrial-waste processing experience at Navoi, a broader critical-minerals development agenda and minerals cooperation agreements with the European Union and the United States. These provide capabilities and channels for investigation; they do not establish the recoverable value of individual deposits. [1] [2] [3] [4] [5]

A defensible national dollar valuation is not yet supported by the evidence reviewed here. Facility-level quantities, grades, mineralogy, recovery, product terms and lifecycle costs must come first. Urgent stabilisation and remediation should proceed independently of the prospect of mineral sales.

The first decision

Approve a 12-month assessment programme, proposed for 2027, with a public spending ceiling of **US\$3 million**. Screen three to five facilities and prepare **up to two pilot tenders** where the evidence supports them. The ceiling is an author-developed planning envelope, subject to priced work packages and an inception review; it is not an engineering estimate or an existing commitment.

The recommended strategy

Policy pillar	Recommended design
Competitive pilot partnerships	Pay for verified test work and agreed deliverables; allocate access rights and liabilities explicitly.
Shared research and testing	Use a coordinated network of existing laboratories before building additional infrastructure.
Targeted financial support	Fund information and additional public benefits through capped, time-limited assistance.
Clear regulation and accountability	Compare recovery with safe stabilisation and closure; retain independent environmental decisions.
Buyer and technology partnerships	Qualify products and processing routes before committing to commercial capacity.

Pilot construction and commercial investment require separate budgets and approvals. Projects may advance only after independent technical, environmental and financial review. Reliable negative results are useful outcomes: they should redirect spending toward further investigation, redesign or rehabilitation.

1 The policy opportunity

Supply security with commercial discipline

Diversified mineral supply is a credible policy objective, but demand growth does not guarantee profitable production. The IEA's 2025 assessment found that the average share held by the top three refining countries for key energy minerals rose from about 82% in 2020 to 86% in 2024, while prices for several minerals weakened. Uzbekistan therefore faces both an opening for new suppliers and competition from established producers. [6]

Copper concentrates, tungsten products and separated rare-earth oxides have different feedstock requirements, processing routes and qualification procedures. Each proposal should identify the product and prospective customer before equipment is selected. Any assumed security-of-supply premium must be supported by commercial terms rather than geopolitical expectations.

The EU Critical Raw Materials Act entered into force in May 2024. Its 2030 benchmarks include EU capacity equivalent to 10% of annual consumption for extraction, 40% for processing and 25% for recycling. These are European policy benchmarks, not purchase commitments to Uzbek suppliers or automatic entitlements to financing. [7]

Build on the existing industrial agenda

The March 2025 government announcement described 76 projects covering 28 minerals, with US\$2.6 billion in investment over the following three years. In June 2026, the President's office reported plans for 120 projects worth US\$4.2 billion for 2026-2030 and expansion of research and technopark capacity in Chirchik. The announcements have different dates and scopes; they should not be added together or presented as dedicated tailings funding. [2] [3]

The proposed programme should establish a defined tailings workstream within that wider effort. Its added value is comparable site information, independent scrutiny and disciplined allocation of support. Existing operators, laboratories and training institutions should be assessed before creating a new agency or campus.

Maintain two coordinated tracks

A **safety and remediation track** should address urgent hazards and long-term liabilities regardless of recoverable value. A **resource-development track** should investigate opportunities that may support commercially viable recovery. Sites may enter both tracks, but investigation of mineral potential must not postpone necessary protection of people, water or infrastructure.

The public objective is to reduce harm and develop projects whose benefits remain credible after costs and liabilities are included. Industrial upgrading, skills and diversified exports are supporting outcomes. A programme that rejects unsuitable projects can still succeed by preventing avoidable expenditure and improving site management.

Assess power and water at the site

National renewable expansion does not establish reliable low-carbon electricity at a processing facility. Require connection capacity, supply terms and interruption allowances. Water studies should cover seasonal availability, competing uses, treatment and absolute withdrawals. Product carbon claims should reflect the complete processing route and actual energy supply.

2 Evidence and the domestic opportunity

What the analysis establishes

This paper draws on selected public documents, official strategies, international standards and a technical company disclosure. It includes no new sampling, site inspections, community interviews, certified resource estimates or engineering designs. Government announcements establish policy intent; company reports illustrate technical claims that require independent validation.

Alternatives are assessed qualitatively against commercial feasibility, technical readiness, administrative demands, environmental and social outcomes, learning and public financial exposure. Comparable site evidence is insufficient for defensible numerical rankings. Stakeholder positions below are questions for consultation, not findings about consent or opposition.

Define and verify the material

Tailings are residues remaining after mineral processing. Their physical stability, chemistry and recovery options differ from those of other mining wastes.

The national environmental report's illustrative summary reports almost 3 billion tonnes of industrial waste in 15 tailings facilities, with data mainly for 2020-2022. This describes a reported waste-management challenge, not a mineral reserve. Sludge ponds, tailings, waste rock, slags and other wastes should be recorded separately and reconciled for overlap. [8]

For each facility, establish dry or wet mass, deposition history, ownership, known hazards and sampling coverage. Grades may vary by depth, location and operating period. A few favourable assays cannot establish an impoundment-wide average. Record the date, method, uncertainty and reviewer for every major estimate.

A domestic precedent, with a clear boundary

An official 2021 account described Navoi's seventh hydrometallurgical plant as capable of processing 15 million tonnes of industrial waste annually for gold recovery. This is evidence of industrial-waste recovery experience. It does not establish current operating performance, the economics of other wastes or recovery of critical minerals. [1]

Where to begin

Provisional search areas are Navoi, Almalyk and tungsten-related waste streams identified with responsible operators. The 2025 announcement identifies tungsten processing at Ingichka as an opportunity, but does not establish the grade, volume or availability of a particular tailings deposit. These are screening candidates, not selected investments. [2]

The initial shortlist should balance technical plausibility, environmental need, clear access and useful learning. Criticality should be stated for each target material and policy objective; gold may support a mixed-metal project without itself establishing a contribution to a critical-minerals strategy. Radioactive materials require a distinct specialist assessment and applicable approvals.

3 International lessons and their limits

International experience supports coordinated investigation, shared technical capability and staged demonstration. National spending announcements alone cannot establish the performance of individual recovery projects.

Table 1. Transferable mechanisms and institutional limits

Policy mechanism	Adaptation for Uzbekistan	Limit on transfer
India: coordinated mission The January 2025 mission combines planned public expenditure with expected investment and includes secondary-source recovery and pilot work. [9]	Assign one programme team responsibility for the work plan, shared data and reporting. Separate public appropriations from expected co-investment.	A national mission does not demonstrate tailings-specific returns or justify copying its spending scale.
Australia: mine-waste atlas Geoscience Australia's atlas supports identification and investigation of secondary mineral potential. [10]	Build a georeferenced facility inventory with common definitions, provenance and a representative sampling strategy.	An atlas identifies prospects. It is not a reserve statement or an investment recommendation.
Canada: research and demonstration The pilot and demonstration programme includes technologies using secondary sources such as tailings. [11]	Commission test work through staged calls that define the technical question and the decision the evidence will inform.	Domestic eligibility and funding terms are not automatically available to Uzbek projects.

Sources: references 9-11. Adaptations and transfer limits are the author's policy interpretation, not evaluations of programme impact.

Capability before construction

A shared service network should begin with laboratory equipment, staffing, quality assurance and demand already in place. Published methods, reliable turnaround and independent checks can be more valuable than a new building. Additional infrastructure becomes justified when a documented service gap, qualified users and sustained operating finance support it.

Match support to the problem

Resource characterisation, process demonstration and additional remediation benefits require different instruments. Their eligibility rules should reflect the specific public purpose. Funding scientific uncertainty is different from subsidising routine production; a well-designed programme should be able to support useful test work that does not lead to a mine or processing plant.

Community participation must also fit local rights and institutions. International examples can inform disclosure, consultation and grievance procedures, but a generic promise of jobs cannot substitute for enforceable environmental obligations or meaningful engagement with affected people.

4 Select projects through decision gates

Each gate should produce a documented decision to advance, redesign, defer or stop. Independent reviewers should assess the evidence required for that decision, not reward movement toward construction for its own sake.



Figure 1. Evidence required before a project advances

Gate one Establish safety and legal access

Before intrusive sampling or excavation, assess facility stability and exposure risks. Resolve material and land access, historic obligations and responsibility for new impacts. Urgent hazards enter the remediation track. Sampling itself must have an appropriate safety plan.

Gate two Characterise representative material

Design sampling around spatial variation, depth and deposition history. Use chain of custody, quality controls, independent analytical checks and mineralogical analysis. Identify harmful constituents and radiological characteristics where indicated. Keep unresolved data visible.

Gate three Compare process and remediation options

Test credible routes against the actual feedstock and target product. Assess recovery, impurities, reagents, energy, water and residual-waste properties. Include safe stabilisation or closure without recovery as a comparator. Higher extraction is not sufficient if it creates a worse residual liability.

Gate four Demonstrate an integrated operating case

A demonstration should test variable feedstock, repeatability, operating continuity, customer acceptance and residue management. Its scale and duration should follow the technical question. Set suspension conditions before trials, and retain monitoring and emergency funding if work stops.

Gate five Authorise or decline commercial development

Require an independently reviewed feedstock model, feasible processing route, credible buyer pathway, realistic lifecycle costs, environmental approvals, allocated liabilities and funded closure. Identify remaining risks and conditions. A failed assessment or pilot must not trigger automatic expansion.

Assess the complete process

BacTech's 2021 gold test disclosure describes bio-oxidation followed by carbon-in-leach cyanidation. Bioleaching should therefore not be described as inherently cyanide-free. The lesson is to evaluate the complete process, contaminants and residues on representative feedstock, rather than transfer a vendor's reported result to an Uzbek site. [14]

5 The five-pillar strategy

5.1 Competitive pilot partnerships

Government should first procure assessment and pilot services, then choose a commercial structure suited to viable projects. Research grants, service contracts, concessions, joint ventures and formal public-private partnerships create different obligations. The structure should follow the public objective and the risks each party can manage.

Qualified bidders should receive the same independently reviewed information. Selection should assess technical evidence, environmental performance, competence, lifecycle costs and total public support requested. A high forecast recovery should not outweigh a more credible process or a safer residual-waste outcome.

Contracts should specify feedstock, access, sampling, reporting and ownership of new data. Allocate legacy contamination, new disturbance, worker safety, residual waste and closure responsibilities without leaving an unassigned gap. Guarantees and purchase commitments should be disclosed and capped even where construction is privately financed.

Payments should follow verified deliverables. A valid negative result is valuable when agreed tests are completed and reliable data supplied. Paying only for metal recovered may encourage selective sampling or discourage honest reporting. Technical failure should be distinguished from non-performance or misrepresentation.

5.2 Shared research and testing capacity

The proposed National Critical Minerals Innovation Hub should begin as a coordinated service network. It should connect laboratories, pilot facilities, operators and universities under common quality and access rules. Planned research expansion in Chirchik is a reason to assess those capabilities before creating a separate institution. [3]

Initial services should include sample preparation, mineralogy, independent assay checks, process testing, environmental characterisation and technician training. Commission work against a published programme of demand. Equipment budgets must include calibration, consumables, maintenance, accreditation and staff retention.

Operators that supply material or sponsor research should not control verification of their own results. Publish methods and non-confidential negative findings, protect legitimate proprietary information, and define rights to use publicly funded outputs. Access should be available on transparent terms to qualified smaller firms as well as established operators.

5.3 Targeted financial support

The strongest initial case for support is information and shared capability that firms may underprovide. Competitive grants or service contracts should state the additional activity, public benefit, maximum contribution and review date. Routine legal compliance should not automatically attract a subsidy.

Later demonstration support should require a credible financing gap and an appropriate sponsor contribution. Cost sharing should reflect risk and the value of proprietary results; a universal matching rate would be premature. Expiry dates, audit rights and remedies for misuse should be agreed before awards.

The five-pillar strategy continued

Financial discipline through scale-up

A profitable project that would proceed without assistance should not receive support merely because it processes tailings. Where additional remediation is proposed, compare verified risk reduction and lifecycle cost with a rehabilitation alternative. Avoid paying for the same benefit through overlapping grants, tax relief and remediation contracts.

Do not set a uniform 70% recovery threshold across minerals and process routes. Assess recovery alongside product quality, water, energy and residual hazards. Sovereign recovery bonds, royalty holidays and price guarantees should not precede a credible project pipeline and explicit appraisal of repayment and fiscal exposure.

5.4 Regulation and environmental accountability

A targeted legal review should start with the Law on Subsoil of 31 October 2024 and the applicable implementing, environmental, water and land rules. It should identify specific gaps rather than presume that a new mining code is required. The proposed arrangements must be checked against the operative framework at launch. [12]

Clarify who controls deposited material, who may grant access, how competing claims are resolved, how secondary products and residues are classified, and who carries past and new liabilities. A recovery operator should not inherit undefined historical obligations; nor should the state absorb new private liabilities without appraisal.

Require a site management plan comparing recovery, stabilisation and closure. Where recovery is technically unsuitable or environmentally inferior, rehabilitation should remain acceptable. A coordinated permit process should reduce duplication while preserving independent environmental and safety decisions.

The Global Industry Standard on Tailings Management provides a reference for lifecycle safety, affected communities, accountability and disclosure. Its principles do not replace domestic permits. Independent geotechnical review, emergency arrangements and funded closure should accompany projects that disturb storage facilities. [13]

5.5 Buyer and technology partnerships

Use existing EU and U.S. cooperation channels for sampling, engineering, training and buyer engagement. Diplomatic agreements are not binding finance or purchase contracts. Prospective customers should review specifications early and test representative samples before a commercial plant is committed. [4] [5]

The first viable product may be a concentrate or intermediate for an existing processor. Compare further domestic refining with other routes using net revenue, investment needs, reliability and retained domestic value. Rare-earth separation requires element-specific mineralogy, proven separation and impurity management; occurrence alone does not justify a plant.

Offtake terms should address quality, pricing, volumes, payment, rejection, delays and termination. Technology agreements should provide training, maintenance information and lawful operating rights. Compare customers, suppliers and transport routes on capability and delivered cost, including border delays and working capital.

6 Institutions and implementation incentives

The programme needs a coordinator with clear delivery responsibilities and reviewers able to withhold support. A charter should separate industrial promotion, technical verification and statutory approvals. Proposed assignments below remain subject to confirmation of legal mandates at launch.

Table 2. Proposed institutional responsibilities

Proposed responsibility	Accountability
Ministry of Mining Industry and Geology	Coordinate the work plan, registry, procurement and reporting; publish reasons for gate decisions.
Ministry of Economy and Finance	Review expenditure, tax support, guarantees and contingent liabilities; authorise changes within its mandate.
Environmental, water and safety authorities	Retain statutory decisions; set applicable requirements for intrusive work, water, residues and closure.
Independent technical review panel	Review sampling, process evidence and cost assumptions; declare conflicts and recommend advance, redesign or stop.
Operators and contracted specialists	Provide access and traceable records; meet contractual and regulatory obligations; remain accountable for their activities.

Address incentives before they undermine delivery

Operators may be reluctant to disclose uncertain inventories or historic liabilities. The programme should offer a clear data protocol, legitimate confidentiality protection and explicit liability boundaries, while preserving existing obligations. Access to public support should depend on adequate disclosure and independent review. These are anticipated design challenges, not findings from stakeholder interviews.

Programme managers may face pressure to announce plants even after adverse results. Their performance measures should reward reliable evidence, timely decisions and risk reduction. Technical reviewers should be appointed transparently, recuse themselves where conflicted and publish non-confidential findings. Any decision to proceed against their recommendation should require written reasons and the necessary approvals.

Communities need a practical role

Consult nearby residents, farmers and water users before tenders are finalised. Disclose material risks and alternatives in accessible language, document how concerns affect design, and provide an independent route for grievances. Agreements should specify measurable commitments for information, training or compensation without substituting for pollution controls or access to remedy.

Coordinate existing functions through a small programme team and scheduled joint reviews. A new agency is unnecessary unless a documented mandate or capacity gap cannot be resolved within current institutions.

7 Compare the policy choices

The preferred approach combines urgent remediation with a sequence of characterisation and conditional demonstrations. Privately viable recovery should remain possible without subsidy. The comparison below is a qualitative judgment under uncertainty, not an estimated ranking of economic returns.

Table 3. Comparison of policy choices

Approach	Main advantage	Main limitation	Recommended role
Remediation without recovery	Addresses hazards without depending on mineral sales.	Needs funding and may forgo recovery at some sites.	Necessary comparator; preferred where recovery is inferior.
Privately led recovery	Can mobilise investment without production subsidy.	Information gaps or additional remediation benefits may remain unfunded.	Use where rights, safeguards and returns support investment.
Broad incentives and immediate expansion	Could accelerate mature, investment-ready projects.	High fiscal exposure; may support poor feedstock or premature capacity.	Do not adopt as the initial national approach.
Inventory and research alone	Builds information with relatively limited commitment.	Does not establish integrated operation or customer acceptance.	First stage, tied to decisions on further work.
Characterisation followed by conditional demonstrations	Combines learning with bounded operating tests and preserves stop options.	Needs disciplined selection, independent review and time.	Preferred development sequence alongside urgent remediation.

Author's appraisal. Relevant criteria are public benefit, cost exposure, technical readiness, administrative demands and reversibility.

Separate the commercial and public cases

A project model should include feed, grade, recovery, payability, product price, charges, transport, operating costs, capital, working capital, taxes and closure. The public appraisal should separately assess resource costs, environmental effects, distribution and the additional benefit of support.

A subsidy is revenue to a project and a cost to the state. Taxes affect project cash flow and government receipts but are transfers within a national social appraisal. Do not add revenue, wages, taxes and avoided remediation costs as though all were separate net benefits. Unpriced harms should remain visible.

Compare recovery with a credible compliant-management or rehabilitation baseline. A modest commercial return may coexist with valuable remediation; an attractive private return may coexist with unacceptable water or residual-waste risks. Document both cases before choosing an instrument.

8 Implementation and public spending

Begin with a bounded assessment phase, not a national plant-construction target. The proposed dates establish an order of decisions; they are not forecasts of successful projects or reasons to bypass evidence.

Table 4. Proposed sequence and approval gates

Phase and timing	Main work	Decision required
Assessment 2027	Registry; screen 3-5 facilities; representative sampling; process tests; baseline and rights studies.	Approve up to two pilot tenders only where evidence supports further work.
Pilots 2028-2029	Process demonstrations; product samples; water and residue tests; customer qualification.	Independent technical, environmental and financial review before investment preparation.
First commercial projects 2030-2032	Detailed engineering; permits; financing; construction and commissioning.	Separate investment approval, realistic cost estimates and bounded public exposure.
Selective expansion 2033-2035	Replicate proven routes; expand services, capacity and markets where justified.	Evidence of sustained performance, finance and public benefit.

Author's proposed schedule. Procurement, seasonality, permits, site access or unsuccessful tests may change timing and scope.

Manage the first twelve months

Months 1-2: establish the charter, data-sharing arrangements and safety screen; obtain priced work packages and confirm laboratory capacity. Approve the detailed sampling design and a scope that fits the ceiling before substantial field commitments. If adequate work cannot be procured, reduce the number of facilities or seek an explicit budget revision.

Months 3-8: complete field characterisation and laboratory work on accessible sites; investigate water, residues and legal constraints; consult affected communities and obtain preliminary buyer feedback. Seasonal monitoring may need to extend beyond the assessment year and must be identified as an outstanding requirement.

Months 9-12: subject results to independent review; compare recovery and rehabilitation pathways; publish decision summaries; and prepare up to two conditional pilot tenders. Completing a tender package is not authorisation to build a pilot or commercial plant.

Maintain a separate route for urgent stabilisation

Emergency works and full remediation are outside the assessment ceiling. Where a safety review identifies urgent action, refer it immediately to the responsible authority and funding process. The resource programme must not become a prerequisite for addressing an existing hazard.

The assessment budget and its assumptions

The proposed US\$3 million ceiling is a policy planning envelope for assessment and tender preparation. It is not derived from contractor quotations. The allocations below preserve a limit on public exposure while making the intended outputs explicit.

Table 5. Illustrative allocation for the initial assessment

Assessment activity	Allocation	Output to commission
Registry, records and screening	US\$300,000	A common data structure, records review and a documented shortlist.
Field sampling and independent analysis	US\$900,000	Approved representative sampling, custody records, assays and analytical checks.
Laboratory process and variability testing	US\$600,000	Comparative process tests, mass balances and results across variable feedstock.
Environmental, water and preliminary stability studies	US\$400,000	Initial baselines, constraints and a defined plan for further specialist studies.
Legal review, consultation and tender preparation	US\$300,000	Access and liability review, consultation record and conditional tender packages.
Independent review, programme audit and contingency	US\$500,000	Independent gate reviews, audit and a controlled reserve for approved uncertainties.
Total proposed ceiling	US\$3,000,000	Assessment only; later phases require separate approval.

Assumptions to confirm before expenditure

The envelope assumes usable access to selected facilities and records, contracted use of existing laboratories, and a focused set of mineral and process questions. It excludes land acquisition, new laboratory construction, pilot equipment, full-scale remediation and commercial engineering. It cannot promise a certified national resource estimate or complete seasonal baselines.

Sampling intensity must follow heterogeneity, safety and the intended decision. Do not divide the budget into an assumed equal amount per facility or dilute quality controls to preserve a site-count target. Detailed assessment should proceed only where a priced, technically adequate scope is affordable.

The inception budget should identify staff time, mobilisation, sample preparation, analytical methods, duplicate checks, specialist services, taxes and foreign-exchange exposure. Separate review and audit fees from the contingency reserve within the US\$500,000 allocation; neither component should be treated as uncommitted spending authority.

Use nominal U.S. dollars for this planning envelope and an explicit exchange-rate and price basis at procurement. Assume no donor or operator contribution until agreed. Record all subsequent support, including tax expenditure, guarantees and closure exposure, alongside direct grants. Any increase in the ceiling requires a revised scope and explicit approval.

9 Outcomes and conditions for success

Measure results against a baseline

In the first year, success means auditable records, representative analyses and defensible decisions. At pilot stage, attention shifts to repeatable recovery, qualified output, process costs and environmental performance. Commercial-stage measures should reflect sustained operation and the full public contribution.

Table 6. Proposed monitoring framework

Outcome	Measure and verification
Reliable information	Complete, dated facility records; reviewed sampling and analytical quality; unresolved fields disclosed.
Commercial readiness	Consistent product specification, customer testing and repeatable operation; distinguish pilot batches from sales.
Environmental improvement	Water withdrawal and quality, dust, stability and residual hazards compared with the baseline and alternatives.
Public value	Direct expenditure, tax relief and guarantee exposure alongside verified additional benefits; fiscal review.
Local participation and capability	Demonstrated competencies, functioning quality systems and grievance resolution; distinguish temporary from continuing jobs.

Set site-specific targets after baseline assessment and before support is awarded. Publish adverse changes and corrective actions as well as progress.

Control the risks that can change the decision

Reprocessing can leave most of the original mass as residue and introduce new handling or chemical risks. Track all significant outputs through a material balance and hazard assessment. Compare absolute water withdrawals, discharge, energy, emissions and long-term storage requirements; a high recycling rate alone is insufficient.

Lower prices, weaker recovery, poor utilisation, higher reagent costs and slower qualification can undermine a project. Test these conditions before investment. Maintain funded monitoring and closure arrangements when production stops, and keep non-commercial sites within the remediation programme.

Conclusion

Uzbekistan has a credible basis for investigating mineral recovery from selected waste streams. Its industrial experience and international relationships can support domestic capability, but the investment case must be built facility by facility.

The next decision is manageable: fund reliable information, compare options and prepare a small number of independently reviewed pilots within a defined public ceiling. Clear rights, shared technical services, targeted support and qualified buyers should enable projects that merit investment. Safe rehabilitation must remain available wherever recovery does not deliver a better outcome.

Appendix A An illustrative economic test

This example preserves the core calculation of the proposed strategy while making its limitations explicit. All inputs are hypothetical. They are not market quotations, Uzbek site data, cost estimates or forecasts.

Table A1. Illustrative annual operating contribution

Input or result	Base illustration	Combined downside
Annual dry feed	1,000,000 tonnes	1,000,000 tonnes
Metal grade	0.20%	0.20%
Contained metal	2,000 tonnes	2,000 tonnes
Recovery	70%	50%
Recovered metal	1,400 tonnes	1,000 tonnes
Payability assumption	100%	100%
Price per payable tonne	US\$8,000	US\$6,000
Sales before charges	US\$11.2 million	US\$6.0 million
Processing cost	US\$6.0 million	US\$6.0 million
Other annual cash costs	US\$1.0 million	US\$1.0 million
Contribution before excluded items	US\$4.2 million	-US\$1.0 million

Excluded: initial and sustaining capital, tax, financing, working capital and closure funding. Other annual cash costs represent an assumed aggregate of transport, treatment and site overhead.

Read the arithmetic correctly

Contained metal equals dry feed multiplied by grade: $1,000,000 \times 0.002 = 2,000$ tonnes. Base sales equal $2,000 \times 0.70 \times 1.00 \times \text{US\$}8,000 = \text{US\$}11.2$ million. Subtracting US\$7 million in annual cash costs leaves US\$4.2 million before the excluded items. This contribution is **not profit or project free cash flow**.

At the base recovery and price, the operating break-even grade is 0.125%. This covers only the assumed annual cash costs. The downside changes both recovery and price, so its negative contribution cannot be attributed to either variable independently.

The illustration assumes constant annual throughput and costs, no ramp-up or downtime, one saleable metal and no by-product credits. Its 100% payability is a simplifying upper-bound convention for this calculation, not a prediction of commercial terms. A real model must specify product deductions without counting them twice.

Sensitivity and investment requirements

Test variables separately before combining them

Under the Table A1 base assumptions, each one-at-a-time change has a distinct effect. These arithmetic tests help identify which information matters most; they do not assign probabilities to project outcomes.

Table A2. Isolated changes and a combined stress case

Change from the base case	Annual contribution
Recovery falls to 50%; other inputs unchanged	US\$1.00 million
Price falls to US\$6,000; other inputs unchanged	US\$1.40 million
Payability falls to 90%; other inputs unchanged	US\$3.08 million
Annual cash costs rise 20% to US\$8.4 million	US\$2.80 million
Recovery 50%, price US\$6,000, payability 90%, costs US\$8.4 million	-US\$3.00 million

How recovery and price interact

The matrix below holds payability at an illustrative 90%, dry feed at one million tonnes, grade at 0.20% and annual cash costs at US\$7 million. Payability is not estimated from a buyer offer; it illustrates a contractual deduction.

Table A3. Annual contribution in US\$ millions, before excluded items

Recovery	US\$6,000/t	US\$8,000/t	US\$10,000/t
50%	-1.60	0.20	2.00
60%	-0.52	1.64	3.80
70%	0.56	3.08	5.60

At 90% payability, 70% recovery and US\$8,000 per payable tonne, the operating break-even grade rises to approximately 0.139%. In general: break-even grade = annual cash costs / (dry feed x recovery x payability x price). Multiply the resulting fraction by 100 to express a percentage.

What an investable model still requires

An investment decision needs a production schedule, variable and fixed costs, capital and sustaining expenditure, working capital, taxes and royalties, closure and post-closure obligations, and a consistent discount-rate and inflation basis. Calculate discounted project cash flows and show financing separately where relevant.

Test feed variability, downtime, commissioning delays, buyer qualification, impurity penalties, exchange rates and cost escalation. Keep the commercial appraisal separate from the public cost-benefit assessment. Neither the positive base contribution nor any cell in these tables establishes investment viability.

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Numbered references support factual claims. Programme design, institutional assignments, budgets, appraisal methods and numerical examples are the author's analytical proposals. Official announcements document intentions or reported capacity at the stated date; they do not establish subsequent completion.

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Evidence and interpretation

The reviewed sources establish a policy context and selected institutional mechanisms. They do not provide a comparable, independently verified dataset on the economics of Uzbek tailings facilities. The recommended assessment programme is intended to address that gap.