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# Institutionally conditioned green bond architecture: A framework for cotton processing in Uzbekistan

**Nomozali Kholmirzayevich Khaydarov**

namozali.xaydarov@gmail.com

ISFT Institute https://orcid.org/0009-0003-2102-6541

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# Abstract

Uzbekistan's five thematic bond issuances since 2021 demonstrate market access but have not financed the water- and energy-intensive processing stage of the country's 134-cluster cotton-textile system. This paper develops a generalisable conceptual model — Institutionally Conditioned Green Bond Architecture (ICGBA) — formalising how sector-specific green finance instruments must be jointly conditioned on a country's institutional-capacity track, its regulatory-transplantation track, and the verification rigour needed to avoid a conditional finance-intensity paradox identified in a companion analysis. We prioritise three proposed eligible-use-of-proceeds categories using the Analytic Hierarchy Process (AHP), cross-validated against the independent Best-Worst Method (Pearson r = 0.996); the resulting weights (water efficiency/effluent treatment: 0.42; energy efficiency/renewables: 0.37; certification/traceability: 0.21) are internally consistent (consistency ratio < 0.01). We build a three-scenario model quantifying illustrative water, energy, CO2, and export effects, and conduct a cost-benefit analysis of a representative cluster-level investment: commercial-rate financing yields a negative net present value (NPV = –USD 2.08 million; IRR = − 4.3%), while a blended concessional structure (50% grant, 50% concessional debt at 4%) renders the investment viable (NPV = + USD 0.53 million; IRR = 9.0%; payback 6.4 years), robust across a range of tariff assumptions tested in sensitivity analysis. We do not claim expert-panel validation of the proposed framework: a two-round Delphi protocol is fully specified but not yet fielded, and we report this gap transparently. Facility-level Uzbekistan ginning-cluster engineering data, sought but not found in the public domain, is substituted with a documented general textile-processing benchmark pending a dedicated engineering audit.



**JEL Classification:** Q56, G23, O16, Q17, C44


# 1. Introduction

Sector-specific green finance design sits at the intersection of two policy problems that are usually studied separately. The first is a governance problem: whether a country's regulatory and capital-market infrastructure is mature enough to support credible, verifiable green-labelled instruments at all — the subject of a companion comparative-governance analysis in this research programme, which finds that green bond framework and taxonomy readiness in this region is driven almost entirely by exposure to a codified external template rather than by generic institutional quality. The second is a corporate-finance problem: whether a specific candidate investment, once eligibility is established, is financeable on terms an issuer or lender would actually accept — a question governance-readiness diagnostics do not, by themselves, answer. This paper's central methodological contribution is to treat these as jointly binding constraints on instrument design, rather than addressing either in isolation, for the specific case of Uzbekistan's cotton-processing sub-sector.

An earlier version of this analysis proposed a sector-specific green bond and green loan framework for Uzbekistan's cotton-processing sub-sector, informed by the country's existing thematic bond experience and by Bangladesh's textile-sector green finance model. That version was explicitly normative: it

proposed eligible-use-of-proceeds categories, three institutional design options, and an illustrative financing-need range, without a formal theoretical model, a quantitative prioritisation of the proposed categories, an economic evaluation of the proposed instrument, or a plan for independent validation. This paper addresses each of these gaps directly.

First, we generalise the framework's underlying logic into a conceptual model — Institutionally Conditioned Green Bond Architecture (ICGBA) — applicable beyond Uzbekistan's cotton sector to any transition economy attempting to launch sector-specific green finance. Second, we replace the qualitative institutional-design discussion with a quantitative Analytic Hierarchy Process (AHP) prioritisation of the proposed use-of-proceeds categories, with all pairwise judgements traced explicitly to cited sources. Third, we build a three-scenario quantitative model translating the financing-need ranges into illustrative environmental and trade outcomes. Fourth, we conduct a cost-benefit analysis of a representative cluster-level investment under both commercial and blended-concessional financing structures, computing net present value (NPV), internal rate of return (IRR), payback period, and sensitivity to discount-rate and benefit assumptions. Fifth, and importantly, we specify — but do not fabricate results for — a rigorous Delphi expert-validation protocol, since genuine stakeholder validation requires primary fieldwork with real banking, ministry, international-financial-institution, and cluster representatives that lies outside what a desk-based analysis can produce; we report this limitation transparently rather than simulating survey data.

The remainder of the paper proceeds as follows. Section 2 reviews the relevant literature and develops the ICGBA conceptual model. Section 3 describes data and methodology for the AHP, BWM, scenario model, and cost-benefit analysis. Section 4 presents the AHP and BWM results. Section 5 presents the scenario model. Section 6 presents the cost-benefit analysis. Section 7 specifies the Delphi validation protocol for future fieldwork. Section 8 discusses implications and limitations, and Section 9 concludes.

## 2. Literature review and conceptual model

# 2.1 Sector-specific green finance instrument design

A growing literature argues that economy-wide green bond frameworks and taxonomies, while necessary, are frequently too coarse-grained to guide instrument design in specific, technically heterogeneous sectors. Climate Bonds Initiative sector-specific eligibility criteria (covering, among others, water infrastructure, buildings, and agriculture) exist precisely because generic taxonomy categories cannot specify the technical thresholds (e.g., water discharge standards, energy-intensity benchmarks) that determine whether a given investment is genuinely decarbonising within a given sector. The International Finance Corporation's Performance Standards framework similarly operates at the level of technical eligibility and monitoring criteria rather than economy-wide categorisation. This sector-specific design question is distinct from, but complements, related work by the present author on green bond credibility and resilience at the instrument level under institutional and geopolitical stress (Khaydarov, 2026a; Khaydarov, 2026b): the former addresses which projects a green bond should

finance, and the latter addresses how robust the resulting instrument is once issued. Our proposed eligible-use-of-proceeds categories (Section 4) and the ICGBA model developed below (Section 2.5) sit within the sector-specific design tradition, applied for the first time, to our knowledge, to Central Asian cotton processing specifically.

## 2.2 Blended and concessional finance

A parallel literature on blended finance — the use of concessional capital (grants, guarantees, below-market-rate debt) to mobilise commercial investment that would not otherwise occur — has developed principles for when and how much concessionality is appropriate. The OECD's Blended Finance Principles and the Convergence Blended Finance market-data ecosystem both emphasise that blended structures should be calibrated to close a specific, quantified viability gap rather than applied as a generic subsidy, and that transparency about the size of the concessional component is itself a governance safeguard against over-subsidisation. This literature directly motivates our cost-benefit analysis (Section 6): rather than asserting that concessional finance is desirable in the abstract, we quantify the specific viability gap (Section 6.3's breakeven grant share) that a blended structure must close for this representative investment, in line with blended-finance design principles rather than treating concessionality as an unquantified assumption.

## 2.3 Multi-criteria decision analysis in sustainable finance prioritisation

Multi-criteria decision analysis (MCDA) methods — principally the Analytic Hierarchy Process (AHP; Saaty, 1980) and, more recently, the Best-Worst Method (BWM; Rezaei, 2015) — are widely used in the energy and sustainability policy literature to prioritise investment categories or policy options against multiple, potentially conflicting criteria. AHP's pairwise-comparison structure produces an interpretable consistency ratio, but requires $n(n-1)/2$ comparisons and is comparatively demanding when many criteria are involved; BWM addresses this by requiring only $2n-3$ comparisons (identifying a best and worst criterion and comparing all others only to these two), at some cost in flexibility. Both methods are ordinarily applied to expert-elicited judgements; a smaller methodological literature has explored their use with judgements derived transparently from secondary sources when expert elicitation is not yet available — the approach we adopt in Section 4.1, and which we cross-validate against BWM in Section 5.4 specifically to test whether our literature-derived AHP judgements are an artefact of the particular pairwise structure chosen or are robust to an alternative elicitation method with different comparison requirements. A further methodological distinction bears on interpretation: AHP's consistency ratio is computed from the full pairwise comparison matrix and penalises intransitive judgements across all criteria pairs simultaneously, whereas BWM's consistency index is computed only from the best-to-others and others-to-worst vectors and is, by construction, less demanding on comparisons not involving the best or worst criterion; a result that is consistent under BWM is therefore a somewhat weaker guarantee than AHP consistency alone, which is one reason we treat the two methods as jointly, rather than either singly, supporting the robustness claim in Section 5.4.

## 2.4 Research gap

No existing study, to our knowledge, has (a) proposed a conceptual model linking climate-governance readiness, green-finance verification sufficiency, and financing-structure viability as jointly binding conditions for sector-specific green finance design; (b) cross-validated a literature-derived multi-criteria prioritisation of sectoral green finance categories using two independent MCDA methods (AHP and BWM); or (c) quantified, via cost-benefit analysis with an explicit breakeven-concessionality calculation, the specific blended-finance structure required to render a representative cotton-processing resource-efficiency investment viable in Uzbekistan. This paper addresses all three gaps.

## 2.5 The ICGBA conceptual model

We propose that a sector-specific green finance instrument's likelihood of achieving genuine (rather than merely nominal) decarbonisation impact is jointly conditioned on three factors, each grounded in this research programme's companion analyses.

**Condition 1 — Track 2 regulatory anchoring**

per a companion comparative-governance analysis, green bond framework and taxonomy infrastructure (“Block D” readiness) is predicted almost entirely by exposure to a codified external regulatory template (via accession conditionality or deliberate mimetic transplantation) and not by general institutional quality. ICGBA's first condition is therefore that a sector-specific instrument must be explicitly anchored to a codified taxonomy — adapted from an external template (EU Taxonomy/Green Bond Standard, or a regional precedent such as Kazakhstan's framework) — rather than assuming generic institutional strengthening will eventually produce one.

**Condition 2 — Verification sufficiency**

per a companion panel-econometric analysis, green finance expansion in this region shows no robust evidence of reducing carbon intensity, and an exploratory, statistically fragile pattern is consistent with green-labelled finance scaling activity without adequate verification of end-use. ICGBA's second condition is that any sector-specific instrument must embed quantitative, independently verified eligibility thresholds (e.g., measured water/energy intensity reduction per unit output) rather than categorical eligibility alone, precisely to avoid this failure mode.

**Condition 3 — Economic viability under realistic financing terms**

the cost-benefit analysis in Section 6 shows that resource-efficiency investment of the kind proposed here is not commercially viable at market lending rates; ICGBA's third condition is that instrument design must incorporate a sufficient concessional (grant or below-market-rate) component, calibrated to the specific investment's cash-flow economics, rather than assuming commercial or quasi-commercial terms will mobilise adequate uptake.

ICGBA thus reframes sector-specific green finance design as satisfying three joint conditions — regulatory anchoring, verification sufficiency, and calibrated concessionality — rather than as a single instrument-design choice.

# 2.6 Boundary conditions and formal propositions

We state ICGBA's scope more precisely through three propositions, each with an associated boundary condition specifying where the model is expected to apply and where it is not.

**Proposition 1**

sector-specific green finance instruments launched without satisfying Condition 1 (regulatory anchoring) will rely on issuer-specific frameworks reviewed only by second-party opinion providers, reproducing rather than closing the taxonomy gap identified at the national level. Boundary condition: this proposition applies to jurisdictions without an existing domestic green bond framework or taxonomy (as in Uzbekistan); it does not apply where a domestic taxonomy already exists and merely requires sectoral extension (as would be the case, for example, in a future Kazakh cotton-sector instrument).

**Proposition 2**

sector-specific green finance instruments launched without satisfying Condition 2 (verification sufficiency) are more likely to exhibit the scale-without-decarbonisation pattern documented at the macro level in the companion panel analysis. Boundary condition: this proposition is strongest where the underlying green finance activity is bank-intermediated and self-reported (as in Uzbekistan's current thematic bond reporting); it is weaker where independent third-party monitoring is already institutionalised (e.g., under IFC or multilateral development bank co-financing, which typically carries independent monitoring requirements regardless of the domestic taxonomy's maturity).

**Proposition 3**

sector-specific green finance instruments launched without satisfying Condition 3 (calibrated concessionality) will exhibit low take-up or high default risk if priced at commercial rates, and the required concessional share is an empirical, sector- and investment-specific quantity rather than a fixed proportion. Boundary condition: this proposition applies to capital-intensive, long-payback resource-efficiency investments of the kind modelled in Section 6; it is less likely to bind for lower-capex, faster-payback interventions (e.g., the smaller Bangladesh benchmark transactions in Table 2 of the original framework), where commercial terms may already be sufficient.

Positioning ICGBA relative to existing frameworks: ICGBA does not replace the EU Taxonomy Regulation, the IFC Performance Standards, or the Climate Bonds Initiative's sector criteria; each of these operationalises Condition 1 or Condition 2 for a specific jurisdiction or sector already. ICGBA's distinct contribution is to specify that all three conditions must be satisfied jointly for a sector-specific instrument in an early-stage green-finance market, and to demonstrate, via the companion diagnostics in

this research programme, that satisfying any one or two conditions without the third (as Uzbekistan's existing thematic bonds currently do — they satisfy something like Condition 1 loosely, via ICMA-aligned frameworks, but not Conditions 2 or 3 for the cotton-processing sector specifically) is insufficient. This is, we argue, a generalisable diagnostic for any transition economy assessing why a nominally available green finance instrument has not translated into sector-specific decarbonisation investment, not only for Uzbekistan's cotton sector.

## 3. Data and methodology

# 3.1 AHP: Category prioritisation

We prioritise the three eligible-use-of-proceeds categories from the original framework — (1) water efficiency and effluent treatment, (2) energy efficiency and renewable integration, (3) sustainable cotton certification and traceability — using the Analytic Hierarchy Process (Saaty, 1980). We define four evaluation criteria — environmental impact, financing urgency/scale, implementation feasibility, and export market relevance — and construct pairwise comparison matrices at both the criteria level and the category level within each criterion. Critically, and unlike a standard AHP application, our pairwise judgements are not derived from an expert panel (which we have not fielded; see Section 7) but are instead explicitly traced to specific cited sources: for example, the water-efficiency category is judged environmentally dominant given Uzbekistan's own green bond impact reporting's explicit focus on water scarcity and groundwater sustainability, while the certification/traceability category is judged most operationally feasible given its comparatively lower capital intensity relative to infrastructure categories, consistent with the smaller-scale Bangladesh benchmark transactions (Envoy Textile, Comfit) relative to the larger IFC–EPIC infrastructure-heavy facility. We report the consistency ratio (CR) for every matrix and treat CR < 0.10 as acceptable per standard AHP practice. Formally, for a pairwise comparison matrix $A = [a_{ij}]$ of order $n$, AHP weights are derived from the normalised principal eigenvector of $A$, and the consistency ratio is computed as $CR = CI / RI$, where $CI = (\lambda_{max} - n) / (n - 1)$ is the consistency index, $\lambda_{max}$ is the matrix's principal eigenvalue, and $RI$ is the random-index benchmark value tabulated for matrices of order $n$ ($RI = 0.58$ for $n = 3$, the order of our category-level matrices, and $RI = 0.90$ for $n = 4$, the order of our criteria-level matrix). All five matrices used in Section 4 (one criteria-level, four category-level, one per criterion) satisfy $CR < 0.01$, an order of magnitude below the conventional 0.10 acceptability threshold, indicating that the source-derived judgements underlying each matrix are highly internally consistent even before the BWM cross-validation in Section 5.4 is applied.

# 3.1b Cross-validation via the best-worst method

To test whether the AHP priority weights in Section 4.1 are an artefact of the specific pairwise-comparison structure AHP imposes, we additionally compute criteria weights using the Best-Worst Method (BWM; Rezaei, 2015). BWM requires identifying, from the same underlying source-derived judgements, a best criterion (environmental impact, consistent with Section 4.1's finding that it receives the highest AHP weight) and a worst criterion (implementation feasibility, the lowest-weighted AHP

criterion), then constructing two comparison vectors — best-to-others and others-to-worst — and solving a linear programme that minimises the maximum inconsistency across all implied pairwise ratios. We report the resulting weights, the BWM consistency index (ξ), and the correlation between AHP and BWM weights in Section 5.4.

# 3.2 Scenario model

We extend the original framework's three financing-need scenarios (Conservative, Intermediate, Broad) with illustrative, explicitly stated assumptions to quantify water savings, energy savings, avoided CO2 emissions, and export-competitiveness uplift. Baseline per-cluster water and energy use (1.2 million m3/year and 8.0 GWh/year respectively) are illustrative mid-size-cluster assumptions; water- and energy-efficiency improvement rates (30/40/50% water reduction and 15/20/25% energy reduction across the three scenarios) are drawn from the Bangladesh and IFC–EPIC benchmark ranges cited in the original framework. CO2 avoidance is computed using an illustrative grid emission factor for Uzbekistan's gas-dominated electricity mix (0.45 tCO2/MWh). Export uplift is computed using an illustrative elasticity (0.8 percentage points of export growth per USD 100 million of compliance-enabling capital expenditure), reflecting the framework's argument that resource-efficiency investment supports buyer-side compliance and market access rather than being independently causal of export growth.

# 3.3 Cost-benefit analysis

We evaluate a representative cluster-level investment (capital expenditure: USD 4.0 million, the midpoint of the Conservative scenario's per-cluster range) over a 10-year horizon. Annual benefits comprise water-cost savings (illustrative industrial water tariff plus treatment cost: USD 0.25/m3, applied to a 30% reduction in the assumed baseline water use), energy-cost savings (illustrative industrial tariff: USD 60/MWh, applied to a 15% reduction in baseline energy use), and an illustrative annual export-premium/market-access benefit (USD 150,000/year) reflecting certified-cotton buyer premiums documented in the Better Cotton Initiative and comparable sustainable-sourcing literature. We compute NPV and IRR under two financing structures — full commercial financing at a 10% discount rate, and the blended concessional structure proposed in the original framework's Option C (50% grant-funded, 50% concessional debt at 4%) — and conduct sensitivity analysis varying the discount rate (8–12%) and the annual benefit estimate (± 20%).

Three methodological choices warrant explicit justification. First, the 10-year evaluation horizon reflects the typical useful life of ginning-stage water-recycling and energy-efficiency capital equipment documented in the Bangladesh benchmark transactions (Section 2), rather than the longer horizons (15–25 years) sometimes used for grid-scale renewable energy infrastructure; a shorter horizon is conservative in the sense that it understates any residual value the equipment retains beyond year 10. Second, the 10% commercial discount rate reflects the approximate cost of commercial local-currency corporate credit documented for Uzbekistan's cotton-textile clusters (Section 2.3 of the original framework notes commercial rates of approximately 20% against subsidised agricultural credit of approximately 5%; we use 10% as a conservative mid-point rather than the higher end of the documented

commercial range, again biasing the analysis against, not toward, our finding that commercial terms are insufficient). Third, we treat the three benefit components (water savings, energy savings, export premium) as additive and independent, which is a simplifying assumption: in practice, water-efficiency and energy-efficiency investments at a single facility are likely to be technically complementary (e.g., a shared capital expenditure programme covering both), which could reduce total capex below the additive USD 4.0 million assumption; we do not attempt to model this complementarity given the absence of facility-level engineering data (Section 8.2), and flag it as a reason our commercial-financing NPV estimate may be conservative rather than as a reason to expect the qualitative commercial-viability conclusion to reverse.

# 4. AHP results: Prioritising use-of-proceeds categories

Table 1 reports the criteria-level pairwise comparison and resulting weights. Environmental impact receives the highest weight (0.424), followed by financing urgency/scale and export market relevance (0.227 each), and implementation feasibility (0.122). The matrix is highly consistent (CR = 0.004).

Table 1
AHP criteria weights

| Criterion | Weight | Rank |
|---|---|---|
| Environmental impact | 0.424 | 1 |
| Financing urgency/scale | 0.227 | 2 (tied) |
| Export market relevance | 0.227 | 2 (tied) |
| Implementation feasibility | 0.122 | 4 |
| *Note: λ_max = 4.010, CI = 0.0035, CR = 0.004 (< 0.10, acceptable). Judgements traced to cited sources per* Section 3.1*, not an expert survey.* | | |

Table 2 reports the category-level weights within each criterion, and the final aggregated priority weights. Water efficiency and effluent treatment ranks first overall (0.418), driven primarily by its dominant weight on the highest-weighted criterion (environmental impact, 0.493). Energy efficiency and renewables ranks second (0.371). Certification and traceability ranks third overall (0.212) despite scoring highest on implementation feasibility (0.460), because feasibility carries the lowest criteria-level weight.

Table 2
AHP category weights by criterion and aggregated final priority

| Category | Env. impact | Financing urgency | Feasibility | Export relevance | Final weight |
|---|---|---|---|---|---|
| 1. Water efficiency/effluent | 0.493 | 0.400 | 0.221 | 0.400 | 0.418 |
| 2. Energy efficiency/renewables | 0.354 | 0.400 | 0.319 | 0.400 | 0.371 |
| 3. Certification/traceability | 0.153 | 0.200 | 0.460 | 0.200 | 0.212 |

*Note: All four category-level matrices have CR < 0.01. Final weight = Σ(criterion weight × category weight within criterion).*

# 4.4 BWM cross-validation of criteria weights

Table 2b reports the Best-Worst Method weights alongside the AHP weights from Table 1, using environmental impact as the BWM best criterion and implementation feasibility as the BWM worst criterion — the same ranking AHP itself produces, so that the two methods are cross-validating rather than definitionally identical. The two weight vectors are very highly correlated (Pearson r = 0.996, p = 0.004), and the BWM consistency index (ξ = 0.021) is well within the range Rezaei (2015) treats as acceptable. This convergence indicates that the criteria prioritisation in Section 4.1 is not an artefact of AHP's specific pairwise-comparison structure: an independent multi-criteria method, applied to the same underlying source-derived judgements but requiring a different and smaller set of comparisons, produces materially the same ranking and near-identical relative weights.

Table 2
b. AHP and BWM criteria weights compared

| Criterion | AHP weight | BWM weight | Difference |
|---|---|---|---|
| Environmental impact | 0.424 | 0.447 | + 0.023 |
| Financing urgency/scale | 0.227 | 0.234 | + 0.007 |
| Export market relevance | 0.227 | 0.234 | + 0.007 |
| Implementation feasibility | 0.122 | 0.085 | −0.037 |

*Note: Pearson r(AHP, BWM) = 0.996 (p = 0.004). BWM consistency index ξ = 0.021 (acceptable per* Rezaei, 2015*).*

# 5. Scenario model: Illustrative environmental and trade effects

Table 3 reports the three-scenario quantification. Under the Conservative scenario (35 clusters, USD 150 million), illustrative annual water savings reach 12.6 million m3, energy savings 42.0 GWh, avoided emissions 18.9 kilotonnes CO2, and export uplift 1.2 percentage points. The Broad scenario (105 clusters, USD 325 million) scales these to 63.0 million m3 of water, 210.0 GWh of energy, 94.5 kilotonnes

of avoided CO2, and 2.6 percentage points of export uplift. We stress these figures illustrate the order of magnitude and direction of plausible effects under stated assumptions; they are not a substitute for facility-level engineering measurement, which should be commissioned once a pilot cohort (Section 5.4 of the original framework) is selected.

Table 3
Illustrative scenario outcomes

| Scenario | Clusters | Capex (USD m) | Water saved (Mm³/yr) | Energy saved (GWh/yr) | CO2 avoided (kt/yr) | Export uplift (pp) |
|---|---|---|---|---|---|---|
| Conservative | 35 | 150 | 12.6 | 42.0 | 18.9 | 1.2 |
| Intermediate | 60 | 215 | 28.8 | 96.0 | 43.2 | 1.7 |
| Broad | 105 | 325 | 63.0 | 210.0 | 94.5 | 2.6 |
| *Note: Assumptions stated in* Section 3.2. *Illustrative scoping figures, not facility-level measurements.* | | | | | | |

We searched for facility-level engineering audits (water and energy consumption per unit of processed cotton) specific to Uzbekistan's ginning clusters and did not locate any in the public domain; national-level statistics exist (e.g., Uzbekistan's cotton farms consume approximately 16 billion m³ of water annually, with water losses from mismanagement and ageing infrastructure estimated at up to 37% of supply), but these describe farm-level irrigation, not processing-stage water use, and cannot substitute for a facility audit. We therefore anchor our baseline per-cluster water-use assumption to the general textile-processing water-intensity benchmark documented in the literature (approximately 100–150 litres per kilogram of fabric processed), rather than to an arbitrary figure, while stressing that this remains a sector-general, not an Uzbekistan-ginning-specific, benchmark. A facility-level engineering audit, commissioned as part of the pilot phase (Section 5.4 of the original framework), remains the necessary step before these figures can be treated as more than illustrative.

Placing the scenario outcomes in national context is informative even at this illustrative level of precision. The Broad scenario's 63.0 million m³ of annual water savings, while substantial in absolute terms, represents well under 1% of the 16 billion m³ Uzbekistan's cotton farms consume annually — a reminder that processing-stage efficiency gains of the kind this paper models address only a small fraction of the sector's total water footprint, the bulk of which lies upstream in irrigation rather than downstream in ginning and processing. This is not a reason to discount the proposed financing facility's value: irrigation-stage water efficiency is already the subject of separate government programmes (drip irrigation and laser land-levelling, which Uzbekistan credits with conserving an estimated 2 billion m³ in 2023 alone), and a processing-stage facility is intended to be complementary to, not a substitute for, these upstream efforts. It does mean that this paper's environmental claims should be understood as sector-specific and processing-stage-specific, not as a claim about the cotton sector's aggregate water footprint, which would require an integrated irrigation-and-processing financing strategy well beyond this paper's scope.

# 6. Cost-benefit analysis

Table 4 reports the CBA for a representative cluster-level investment (USD 4.0 million capex) under commercial and blended-concessional financing. Under full commercial financing at a 10% discount rate, annual benefits (water savings USD 90,000; energy savings USD 72,000; export premium USD 150,000; total USD 312,000/year) are insufficient to justify the investment: NPV is –USD 2.08 million and IRR is –4.3%, with a simple payback of 12.8 years against a 10-year evaluation horizon. Under the blended concessional structure proposed in the original framework (50% grant-funded, remaining 50% financed as concessional debt at 4%), the effective capital outlay falls to USD 2.0 million, and the investment becomes viable: NPV = + USD 0.53 million, IRR = 9.0%, payback = 6.4 years.

Table 4
Cost-benefit analysis: commercial vs. blended concessional financing

| Metric | Commercial financing | Blended concessional (50% grant + 50% debt @ 4%) |
|---|---|---|
| Effective capex (USD) | 4,000,000 | 2,000,000 |
| Annual benefit (USD) | 312,000 | 312,000 |
| Discount rate | 10% | 4% (concessional debt cost) |
| NPV | –USD 2,082,895 | +USD 530,599 |
| IRR | –4.3% | 9.0% |
| Payback period | 12.8 years | 6.4 years |

We additionally compute the breakeven grant share required for NPV ≥ 0 at an 8% discount rate: approximately 50% of capex must be grant-funded for the investment to break even, confirming that ICGBA's third condition (calibrated concessionality) is not a marginal design refinement but a binding requirement for this representative investment's viability. Table 5 reports the sensitivity of NPV and IRR to ± 20% variation in annual benefits and 8–12% variation in the discount rate under the commercial-financing structure; NPV remains negative and IRR remains below zero across the entire sensitivity range, indicating this conclusion is not an artefact of a single point assumption.

Table 5
Sensitivity analysis (commercial financing structure)

| Benefit assumption | NPV @ 8% | NPV @ 10% | NPV @ 12% | IRR |
|---|---|---|---|---|
| –20% | –USD 2.33m | –USD 2.47m | –USD 2.59m | –7.8% |
| Base case | –USD 1.91m | –USD 2.08m | –USD 2.24m | –4.3% |
| + 20% | –USD 1.49m | –USD 1.70m | –USD 1.88m | –1.2% |
| *Note: IRR is invariant to the discount rate by construction; it varies only with the benefit assumption.* | | | | |

Table 5b extends the sensitivity analysis to the underlying tariff assumptions themselves (water tariff USD 0.15–0.35/m³; energy tariff USD 45–75/MWh), which jointly determine the annual benefit figure used throughout Section 6. Under commercial financing, NPV remains negative across the entire tariff range tested (from –USD 2.41 million at the lowest tariff combination to –USD 1.75 million at the highest), confirming that the commercial-viability conclusion is not sensitive to reasonable tariff uncertainty. Under the blended concessional structure, NPV is positive across the entire same range (from + USD 0.09 million to + USD 0.97 million), with IRR ranging from 4.9% to 12.8% — indicating that the qualitative conclusion (concessional financing is necessary and sufficient to render the investment viable) is robust to tariff assumptions, even though the precise magnitude of viability is naturally tariff-sensitive.

Table 5
b. Sensitivity to water and energy tariff assumptions

| Water tariff (USD/m³) | Energy tariff (USD/MWh) | NPV, commercial (10%) | NPV, blended concessional (4%) | IRR, blended |
|---|---|---|---|---|
| 0.15 | 45 | –USD 2.41m | +USD 0.09m | 4.9% |
| 0.25 | 60 (base case) | –USD 2.08m | +USD 0.53m | 9.0% |
| 0.35 | 75 | –USD 1.75m | +USD 0.97m | 12.8% |

*Note: Full 3×3 tariff grid computed; table reports the low/base/high diagonal for brevity. NPV is negative under commercial financing and positive under blended concessional financing at every one of the nine tariff combinations tested.*

# 6.4 Synthesising the AHP, scenario, and CBA results

The three quantitative exercises in Sections 4–6 are designed to inform each other rather than stand independently. The AHP/BWM prioritisation (Section 4) identifies water efficiency and effluent treatment as the highest-priority use-of-proceeds category, driven primarily by its environmental-impact weight; the scenario model (Section 5) then quantifies what a financing programme weighted toward this priority could plausibly achieve at three different scales; and the CBA (Section 6) tests whether a representative investment of the kind the scenario model envisages is financeable at all under realistic terms. Read together, they support a specific, falsifiable claim: a cotton-processing green finance facility that (i) allocates the largest share of proceeds to water-efficiency and effluent-treatment categories, consistent with the AHP/BWM priority ranking, (ii) is sized within the Conservative-to-Intermediate scenario range (Table 3) rather than the Broad range, given the financial fragility documented for the cluster system, and (iii) is structured with a grant component at or above the approximately 50% breakeven threshold identified in Section 6.3, would be both priority-consistent and financially viable on this paper's assumptions. A facility that violates any one of these three conditions — for example, one that is AHP-inconsistent in its allocation, sized at the Broad scenario without commensurate concessional financing, or structured with a grant share below the breakeven threshold — would not be, on the same assumptions. This synthesis also clarifies what would falsify the paper's central claims. If a future

facility satisfying all three conditions were fielded and subsequently failed to achieve measured water- and energy-intensity reductions consistent with the Bangladesh-benchmarked assumptions in Table 2, that would falsify the scenario model's specific parameters without falsifying ICGBA's structural claim that regulatory anchoring, verification sufficiency, and calibrated concessionality are jointly necessary; conversely, if a facility satisfying only one or two of the three ICGBA conditions were fielded and nonetheless achieved robust, independently verified decarbonisation outcomes, that would cast doubt on ICGBA's structural claim itself, not merely on this paper's parameter estimates. We consider this second, higher-stakes test — whether partial satisfaction of the three conditions is sufficient in practice — the more theoretically important one for future research to pursue, since it speaks directly to whether the three-condition structure, rather than any single condition, is doing the analytical work ICGBA claims for it.

## 7. Proposed expert validation protocol (fieldwork not yet conducted)

We specify, for future primary data collection, a two-round Delphi protocol to validate the ICGBA framework and the AHP priority weights in Section 4 against practitioner judgement. We report the protocol design only; no survey has been fielded, and no results are reported in this paper. We include this section because a rigorous validation design is itself a methodological contribution, and because transparently distinguishing “protocol specified” from “results obtained” is, in our view, preferable to omitting the topic or, worse, presenting simulated responses as data.

## 7.1 Panel composition

We propose a purposive panel of 16–20 experts stratified across four stakeholder groups, each represented by at least four panellists: (i) commercial and state-owned bank representatives with green/sustainable finance mandates (e.g., Agrobank, UzPSB, SanoatQurilishBank); (ii) Ministry of Economy and Finance and Central Bank officials involved in the SDG/green bond framework; (iii) international financial institution staff with active Uzbekistan green finance engagements (e.g., IFC, AIIB, GGGI, EBRD); and (iv) cotton-textile cluster management representatives, sampled to include both large export-oriented clusters and smaller processing-focused clusters.

## 7.2 Instrument and rounds

Round 1 would present the three ICGBA conditions (Section 2), the three eligible-use-of-proceeds categories and their AHP/BWM weights (Section 4), and the three institutional design options from the original framework, asking panellists to rate each on 5-point Likert scales for feasibility, priority, and expected impact, with open-ended justification fields. Round 2 would feed back anonymised Round 1 aggregate ratings and dispersion statistics to panellists and ask them to revise or justify their ratings, following standard Delphi practice. We propose defining consensus as an inter-quartile range (IQR) ≤ 1 scale point on a given item after Round 2, with items failing to reach consensus flagged for a third round or qualitative discussion.

Two design choices merit brief justification. First, we propose two rounds rather than the three or more sometimes used in Delphi applications with larger or more heterogeneous panels: with a 16–20-member panel stratified into four relatively cohesive stakeholder groups (Section 7.1), two rounds are typically sufficient to reveal whether disagreement is genuine and persistent or resolves once panellists see the distribution of others' initial ratings, and a third round should be reserved for items that specifically fail the Round 2 consensus threshold rather than applied uniformly, to limit respondent fatigue and attrition across rounds. Second, we propose Likert-scale ratings rather than asking panellists to complete a full AHP or BWM pairwise-comparison exercise directly: while a practitioner-elicited AHP/BWM exercise would be the most direct like-for-like replacement for our literature-derived judgements, pairwise comparison tasks impose a higher completion burden that risks reducing response rates precisely among the busiest, most senior stakeholders (ministry officials, bank executives) whose input matters most; Likert ratings on the same categories and options, collected alongside open-ended justifications, would allow the research team to reconstruct approximate pairwise judgements for a subsequent researcher-conducted AHP/BWM re-estimation without imposing the full comparison burden directly on respondents.

## 7.3 Use of results

If fielded, the resulting consensus ratings would be used to (i) validate or revise the AHP pairwise judgements in Section 4.1 with practitioner-elicited comparisons, replacing the literature-derived judgements used here; (ii) stress-test the CBA assumptions in Section 6.3 (particularly the grant-share and benefit assumptions) against practitioner expectations of realistic concessional terms; and (iii) assess perceived feasibility of the three institutional design options ahead of any pilot implementation. We recommend this fieldwork as the immediate next step before any of this paper's illustrative figures are used to inform an actual financing decision.

# 8. Discussion and limitations

## 8.1 What this revision adds, and what it still does not resolve

This revision replaces normative assertion with four quantitative methods (AHP, BWM, scenario modelling, CBA) and one explicit theoretical contribution (ICGBA), directly responding to the critique that the original framework was descriptive rather than evaluative. The CBA finding — that commercial financing cannot render this investment viable, while a specific, quantified concessional structure can — is, in our view, the paper's strongest new result, because it is falsifiable, sensitive to stated assumptions that are fully disclosed, and directly actionable for instrument design. The AHP prioritisation is internally consistent, traceable to specific sources, and cross-validated against an independent MCDA method (BWM, Section 5.4), but is not, and should not be presented as, a substitute for the practitioner validation specified in Section 7. Readers should treat the AHP/BWM weights and CBA point estimates as a

rigorous illustrative baseline for the fieldwork in Section 7 to test, refine, or overturn, not as validated policy parameters.

It is worth being precise about what the AHP–BWM convergence in Section 5.4 does, and does not, demonstrate. It demonstrates that our source-derived judgements are being aggregated consistently — that is, the ranking is not an accident of AHP's particular pairwise-comparison mechanics, since an independently structured method (requiring different, fewer comparisons, anchored to different reference points) produces materially the same result. It does not demonstrate that the underlying judgements themselves are correct, since both methods were fed the same source-derived inputs; a bank officer, a ministry official, and a cluster manager could, in principle, all disagree with our reading of the cited sources while agreeing that whichever inputs are used are being aggregated consistently. This distinction — between aggregation validity and input validity — is precisely why Section 7's Delphi protocol targets the inputs (practitioner ratings) rather than proposing yet another aggregation method: further methodological triangulation of the same author-derived inputs would add limited additional evidentiary value at this stage, whereas independent practitioner input would not.

# 8.2 Limitations

Four limitations should be stated plainly. First, the AHP pairwise judgements, while individually justified from cited sources and cross-validated against an independent method (BWM, Section 5.4), are constructed by the authors rather than elicited from the practitioner panel specified in Section 7; this is a genuine limitation, not a methodological choice, and Section 7's protocol exists specifically to remedy it. The BWM cross-validation shows the AHP result is not an artefact of one method's comparison structure, but it cannot substitute for the independent information content that real practitioner disagreement would reveal — both methods, after all, were fed the same underlying source-derived judgements, so their convergence demonstrates internal consistency, not external validity against practitioner opinion. Second, the scenario model and CBA rely on illustrative unit-cost, tariff, and elasticity assumptions, anchored where possible to documented sector-general benchmarks (Section 5) rather than facility-level engineering data for Uzbekistan's cotton-processing sector specifically, which does not yet exist in the public domain; a dedicated technical due-diligence study (recommended in the original framework) remains a prerequisite before any actual instrument is sized. Third, the ICGBA conceptual model, while grounded in this research programme's companion empirical analyses, has itself not been tested outside the Uzbekistan cotton-processing case; extending it to other sectors or countries is a natural direction for future comparative research. Fourth, the CBA in Section 6 is conducted entirely in US dollars and does not explicitly model exchange-rate risk between the Uzbek soum and the US dollar, even though the tariffs, costs, and revenues underlying a real-world cluster-level investment would in practice be denominated substantially in local currency while much of the concessional debt financing modelled in Section 6.2 (following the precedent of Uzbekistan's own dollar- and soum-denominated thematic bonds) could be either dollar- or soum-denominated; currency mismatch between soum-denominated operating cash flows and dollar-denominated debt service is a material risk for any real cluster-level facility that this paper's single-currency CBA does not capture, and

a full financial appraisal ahead of actual instrument design should model this explicitly, potentially drawing on currency-hedging structures already used in Uzbekistan's sovereign and corporate thematic bond issuances.

## 8.3 Generalisability and external validity

A natural question is whether ICGBA's three conditions, and the methodological package used to operationalise them here, generalise beyond Uzbekistan's cotton sector. We see three dimensions along which generalisability should be assessed separately rather than assumed jointly. First, conceptual generalisability: Conditions 1–3 are derived from mechanisms (regulatory transplantation, verification economics, and blended-finance viability gaps) that are not specific to cotton processing or to Uzbekistan, and we would expect the same three-condition structure to apply to other sector-specific green finance efforts in other early-stage green-finance transition economies (e.g., a prospective steel-decarbonisation green loan facility in Kazakhstan, or a leather-tanning effluent-treatment facility in a South Caucasus economy), subject to the boundary conditions stated in Section 2.6. Second, methodological generalisability: the AHP/BWM cross-validation, scenario modelling, and CBA-with-breakeven-concessionality approach is a portable methodological package that does not depend on cotton-specific parameters and could be re-applied, with sector-appropriate unit costs and tariffs, to any candidate sector. Third, and most restrictively, parameter generalisability: the specific numerical results — the AHP/BWM weights, the illustrative financing-need ranges, the 50% breakeven grant share — are calibrated to Uzbekistan's cotton-processing context and Bangladesh-benchmark unit costs, and should not be transferred to another sector or country without re-estimation. We therefore characterise ICGBA as conceptually and methodologically generalisable but parametrically country- and sector-specific, a distinction we consider important for readers assessing whether, and how, to apply this paper's approach elsewhere.

# 9. Conclusion

This paper developed a conceptual model (Institutionally Conditioned Green Bond Architecture), a quantitative prioritisation of proposed financing categories cross-validated across two independent multi-criteria methods (AHP and BWM, Pearson r = 0.996), an illustrative scenario model linking financing scale to environmental and trade outcomes, and a cost-benefit analysis showing that commercial financing cannot render representative cluster-level resource-efficiency investment viable while a specific blended concessional structure can (NPV turning from –USD 2.08 million to + USD 0.53 million, with the qualitative conclusion robust to tariff sensitivity testing across a nine-point grid). We specified, but did not fabricate results for, a two-round Delphi protocol for practitioner validation, treating primary stakeholder fieldwork as necessary future work rather than substituting simulated data. Together, these additions move the analysis from a normative proposal toward a theoretically grounded, quantitatively evaluated, and transparently limited framework.

Read alongside its two companion analyses in this research programme, this paper completes a three-part diagnostic-to-design sequence: the comparative-governance analysis establishes that Uzbekistan's

green bond and taxonomy infrastructure gap is a regulatory-transplantation problem, not a generic institutional-quality problem; the panel-econometric analysis establishes that scaling green finance without adequate verification carries a documented, if statistically fragile, risk of decoupling from actual decarbonisation; and this paper shows what a sector-specific instrument designed to respect both findings — anchored to a codified taxonomy, embedding quantitative verification thresholds, and calibrated to a demonstrated concessionality requirement — would need to look like, and what it would cost. No single paper in the sequence would support the sector-specific policy recommendations this paper makes; it is the combination of comparative diagnostic, causal caution, and instrument-level economic evaluation that does.

The explicit next steps, in priority order, are: (i) fielding the Section 7 Delphi protocol with real banking, ministry, international-financial-institution, and cluster stakeholders, to replace this paper's literature-derived AHP/BWM judgements with practitioner-elicited ones; (ii) commissioning a facility-level engineering audit of water and energy use in a representative sample of cotton-textile clusters, to replace the sector-general benchmarks used throughout Sections <link rid="Sec16">5</link>–6 with Uzbekistan-specific measurements; and (iii) testing the ICGBA model's conceptual and methodological generalisability (Section 8.3) by applying the same three-condition diagnostic and AHP/BWM-scenario-CBA methodological package to at least one additional sector or transition economy, which would allow the parameter-specific findings of this paper to be distinguished empirically from the model's more general structural claims.

## Declarations

# Funding

No external funding was received for this study.

# Declaration of Competing Interest

The author declares no conflicts of interest in this paper.

# Data Availability

The AHP and BWM criterion weights and cross-validation, the multi-criteria category weighting, the scenario-model results, and the cost-benefit analysis results (including sensitivity to discount rate and tariff assumptions) are archived with a permanent DOI at https://doi.org/10.5281/zenodo.21371311. The underlying pairwise comparison matrices and the full source list for each criterion are available from the corresponding author upon reasonable request. No primary survey or interview data were collected for this paper; the proposed Delphi protocol (Section 7) has not yet been fielded.

# Code Availability

The Python code used for the cost-benefit analysis and sensitivity testing is available from the corresponding author upon reasonable request.

# CRediT Authorship Contribution Statement

N.K. Khaydarov: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing.

# Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

AI tools used: Claude (Anthropic, Claude Sonnet 4.5/5 models). How used: to assist with statistical analysis and modelling (AHP and BWM weight computation, scenario modelling, cost-benefit analysis and sensitivity testing), literature identification and verification, data organisation, and drafting of the manuscript text under the author's direction. Where in the article: throughout Sections 3–6 (methodology, results, and cost-benefit analysis) and in the drafting of the surrounding text. The author reviewed, verified to the extent described in this paper, and takes full responsibility for the accuracy, integrity, and content of this publication.

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