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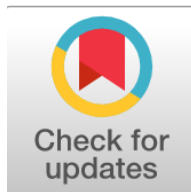
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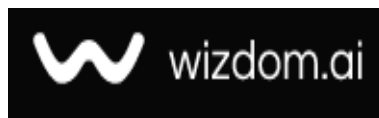
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A Verification-Gated Blended Finance Waterfall for Energy Efficiency Projects in Uzbekistan

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Abstract

General Background Energy efficiency deployment faces severe commercial hurdles because cash flows are generated through avoided expenditures rather than conventional product sales. **Specific Background** Uzbekistan aims to scale up demand-side efficiency investments by combining domestic banking assets, international development funds, and public resources to meet national green transition objectives. **Knowledge Gap** Existing frameworks fail to specify when public allocations should remain recoverable, how physical performance decouples from tariff fluctuations, and how measurement uncertainties alter grant conversions. **Aims** This study designs a transaction-level blended finance waterfall that conditions the release of public capital upon independent ex-post performance validation. **Results** Applying a synthetic 100-unit project structure reveals that integrating a 10% performance-linked public tranche reduces the weighted average cost of capital from 18.0% to 11.0%, lowers total scheduled financing services to 15.21 units, and increases the verified savings coverage ratio to 1.23. **Novelty** This model decomposes green project eligibility into separate decisions based on real physical generation, monetary debt capacities, and distinct fiscal risk exposures instead of a static green label. **Implications** Regulators can deploy this mechanism to pilot sustainable modernization strategies across public infrastructure, industrial operations, and district heating networks without creating unbacked public liabilities.

Keywords: Blended Finance, Energy Efficiency, Performance Verification, Results-based Finance, Uzbekistan

Key Findings Highlights

Blended waterfalls decrease the weighted average cost of capital by seven percentage points.

Underperforming assets triggers technical diagnosis and conditional restructuring rather than automated grant conversion.

Decoupling performance metrics prevents utility tariff movements from dictating fiscal support limits.

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1. Introduction

The main financing challenge on the energy efficiency side is not a lack of engineering possibilities, but rather in how projects create value. A retrofit typically does not generate new sales revenue; it reduces future expenses. Therefore, lenders need to evaluate whether the anticipated decrease in electricity, gas, heat, water or maintenance costs is stable enough to satisfy debt service. This question is important at the moment, when global energy investment was projected to be approximately USD 3.3 trillion in 2025, of which over USD 2.2 trillion were to clean energy, networks storage efficiency and low-emission supply [9,10]. The availability of capital may be growing, but it does not flow to all projects on a level playing field.

While previous research details some aspects of this allocation problem. The source and goal of finance determines what technologies will be funded at what stage [1,5,6]. Green bonds are evidence of issuer commitment and facilitate wider investor participation [2,3]; guarantees, concessional loans, and state investment banks take risks or maturities that commercial lenders will not do at all

[4,6-8]. These instruments are not automatically beneficial, however. A subsidy paid at approval may weaken incentives to operate and maintain the asset, and public money may merely replace finance that the market would have supplied anyway.

These design issues are particularly relevant for Uzbekistan. 2030 targets in the national green-economy programme include 15 GW of renewable capacity, a renewables share of over 30% in electricity generation, at least a 20% gain of energy efficiency in industry, a reduction in energy intensity per unit of gross domestic product by 30%, and a drop in greenhouse-gas intensity compared to 2010 by no less than 35% [15]. The energy policy direction was set from previous programs on renewable energies, public-private partnership, efficiency technologies and investment incentives [16-18]. However, at the same time, latest estimates still indicate a significant generation and networks financing gap with 2023 average annual needs in demand-side efficiency projects for new development conservatively also above \$1 trillion [14,24].

But the immediate cash-flow problem arising from capital outlay for a solar or wind plant is not present with an efficiency retrofit. Large generation projects will likely depend on a power-purchase agreement as well as project-finance structures. Payback comes from the gap between an indexing baseline and true usage: a factory retrofit, a re-fit of a school call, an upgrade of chiller pumping, or rehabilitation of district-heating. That difference is bankable, depending upon audit and metering quality and operating assumptions; contractual allocation of performance risk; and verifier credibility. The technical responsibility may be taken on by an energy-service company, but a financing gap remains where public clients are constrained in their budgets or banks do not accept savings as a source for repayment [11,12,19-21].

The research question is hence not how to mix public and private funding but rather at what moment should public support be non-repayable. The answer is a capital waterfall that is gated off by verification. The financing package of recoverable support includes a subordinated public tranche, bankable only by provision of independently verified, normalized physical savings. A debt-service coverage test is conducted separately to verify monetary savings. The mechanism is intentionally sparse: it only applies to those transactions for which the principle output avoided energy consumption. Renewable electricity generating projects must instead follow a different rule that is based on verified generation.

2. Methods

The design of the analysis was done in four interrelated stages. First, principles of blended finance, public additionality and energy-performance contracting were found through documentary analysis (and measurement and verification). Second, institutional mapping allocated decisions and evidence to the developer owner, energy service company, bank, development financier, public authority and validator. Third, the financed calculation was structured and tested on a 100-unit synthetic transaction based on this annuity. Lastly, sensitivity analysis evaluated the effect of alternative physical-performance thresholds on grant conversion rates. These stages are built around the academic and institutional literature as found in [1-8,19-24].

Your unit of analysis is one energy-efficiency investment with an observable counterfactual: energy spend that would have happened without it. The types of appliances on which the proposed rule are applicable include equipment replacement, public-building renovation, industrial heat recovery, efficient irrigation pumps for district-heating rehabilitation as well as street lighting. Cases where the contract includes continuously metered off-site generation combined with demand reduction and physically subtracts generation from avoided purchases from the grid, include distributed solar only. To be accepted into the model, a project must have an approved baseline, M&V plan (which is written) that will describe the independent verifier's measurements as they are conducted using calibrated meters and also identify a project owner who will be clearly held accountable.

The total project cost (100) is essentially marked in order to reproduce the calculation, and share within sponsor equity, commercial bank debt, concessional debt, a performance-linked public tranche and ESCO deferred remuneration. The WACC formula is $WACC = \sum (s_j \times c_j)$, where s_j is the share of source j and c_j is its cost (annual pre-tax). Total Scheduled Financing Service (TFS), expressed as $ADS_{debt} + ESCO_{deferred}$, where $ADS_{debt} = \sum [P_j \times r_j(1+r_j)^{n_j} / ((1+r_j)^{n_j} - 1)]$. The government hasn't revealed how much it'll lend to private shareholders, but the "public tranche" is five-year interest-free subordinated debt with a two-year grace period. It does not go into performance-year TFS; any remaining balance not converted is repaid in years 3-5. Your base case involves one currency, end-of-period annual payments, no inflation, tax shield or foreign-exchange mismatch guarantees. M&V costs, which are external to WACC, have to be separately budgeted

in a true deal

Engineering performance and financial affordability do not yield the same result, which is why two different metrics are used. VSCR is MVS / TFS where MVS is monetized independently verified annual savings. A VSCR lower than 1.0 indicates financing insufficiency; a VSCR score of between 1.00 and 1.19 leaves marginal leeway, while a score of at least 1.20 is wellingtons are setting as an initial test benchmark for UK Physical performance: $qE = EPV / ECT$, where EPV is an estimate of verified energy savings normalized to a certain period (e.g., daily) and ECT is a contracted energy-saving target. Public additionality is subsequently recorded via $L_{nonbudget} = \text{non-budget capital} / \text{committed public support}$, $L_{private} = \text{private commercial capital} / \text{committed public support}$ and $L_{cash} = \text{total mobilized financing} / \text{actual public cash outlay}$. Committed public support for these ratios consists of both the size of the public tranche itself and the capped exposure under the guarantee.

For the sake of this discussion, let L denote the lower threshold for performance defined beforehand (again at financial close). When $qE < L$ no grant conversion, $(L, 1.00)$, the fraction converted is $(qE - L) / (1 - L)$; $qE \geq 1.00$ the entire eligible tranche converts. The base case is $L = 0.70$ and the alternatives are valued at 0.60 and 0.80, respectively. Where measurement uncertainty is significant, we use the lower bound of the estimated savings interval (rather than the point estimate) in making a decision. Thus, a gap does prevent an unsupported fiscal transfer but not automatically cancelling the project, as it could respond with technical correction, new audit, debt restructuring or repayment of the recoverable tranche.

For the Facilities with isolated or individual equipment, the pilot uses International Performance Measurement and Verification Protocol (IPMVP) Option B wherever feasible; whole-facility interventions may employ Options C. The baseline should typically extend back 12 continuous months and be normalized for relevant changes in weather, output, occupancy, operating hours or water delivery. Before financial close, the parties must negotiate meter calibration, data completeness, treatment of missing observations, verifier independence and uncertainty and dispute resolution 19,20. This numerical exercise is not a quote from lenders or an assessment of an Uzbek completed project but rather a policy simulation. Its interest rates and thresholds, and leverage values must therefore be recalibrated in light of portfolio evidence on savings, defaults, guarantee calls, and the fiscal outcomes

Table 1. Core financial assumptions and instrument specification

Assumption	Synthetic base case	Treatment in calculation
Currency and price basis	Single nominal unit; no inflation or FX mismatch	All cash flows are directly comparable
Tax treatment	Pre-tax; no interest tax shield	WACC is a policy-comparison metric
Commercial / concessional debt	14% for 7 years / 6% for 10 years	End-of-period annuity
Public tranche	10 units; 0%; 5 years; 2-year grace; subordinated	No performance-year service; unconverted balance repaid in years 3-5
Guarantee	20% of commercial bank principal; maximum exposure 9 units	Zero fee in base case; exposure included only in committed-support ratios
M&V and transaction costs	Excluded from WACC and TFS	Must be separately budgeted and tested in pilots

Figure 1.

Table 2. Financing barriers and the proposed transaction-level response

Financing problem	Conventional response	Verification-gated response	Evidence required
High upfront cost	Large equity contribution or high-cost debt	Concessional layer and partial guarantee reduce financing cost	Financial model; lender term sheet
Savings are uncertain	Grant paid at approval or savings ignored	Public tranche converts only after measured savings	Energy audit; M&V plan; meter data
Weak collateral	Asset-based security or rejection	Savings cash flow and ESCO performance obligation supplement security	EPC contract; savings guarantee
Fragmented public support	Separate subsidy, credit, and guarantee schemes	Single capital waterfall with defined priority and triggers	Inter-creditor agreement; public-support rules
Greenwashing risk	Technology label used as eligibility	Eligibility, additionality, and ex-post performance are separate gates	Taxonomy evidence; independent verification

Figure 2.

Note: This rule supplements, rather than substitutes for, technical due diligence, environmental assessment, procurement

review, and borrower credit analysis.

3. Results

3.1. Verification gates and capital waterfall

Verification is built into the transaction sequence rather than added after disbursement. At the first gate, the project must establish green eligibility and measurable additionality against a business-as-usual baseline. The second gate concerns financing readiness: cash-flow assumptions, procurement, implementation responsibility, security, and allocation of risk must be documented before financial close. The final gate is ex-post performance. Proportional or full conversion of the public tranche can only be authorized based on savings tracked under the pre-agreed M&V plan.

This order changes the scope of what is asked through the budget. Public resources only buy a share in the asset and these are not treated as an entitlement at approval. They can help mitigate complexity by reducing the blended financing cost, absorbing a capped portion of lender exposure and paying on performance delivered. A tranche is a receivable if there is not enough evidence, and the bond created as part of this guarantee will be uncalled just because the savings target has been missed.

Technical diagnosis and corrective action precede any restructuring, recovery, or fiscal loss.

Table 3. Verification gates, financing actions, and corrective responses

Stage	Gate or decision	Financing action	Failure response
Pipeline formation	Energy audit and baseline approved	Preparation assistance may be provided	Revise audit or remove project
Green eligibility	Eligible technology and measurable additionality	Project enters the financing portfolio	No green-finance status
Financial close	Cash flow, procurement, security, and M&V plan approved	Equity, commercial debt, concessional debt, and recoverable public tranche committed	Restructure capital stack
Implementation	Installation and metering evidence complete	Construction payments released by milestones	Suspend payment and correct defects
Performance year	Independent verifier confirms normalized savings	Public tranche converts proportionally or fully into a grant	Retain as repayable support; re-audit
Operation and recycling	Debt service and savings remain compliant	Repayable funds and unused guarantee capacity are recycled	Restructuring or recovery

Figure 3.

3.2. Synthetic project and financing effects

For instance, in our example, the project costs 100 units and will produce annual monetized cost savings of 18.7 units. The benchmark has the usual ratio of 30 units sponsor equity and 70 units seven-year commercial debt at an interest rate of 18%. It brought ultimate sponsor equity down to 15 units required from commercial debt, and a blended 45 group asset up-front funding costs, adding therefore 25 of ten-year concessional debt, but also added a subordinated public tranche equal to 10; and deferred ESCO remuneration (5). The public tranche has no service requirement during the performance year. This later treatment is contingent on those fiscal savings being real, where it can fully convert, partly convert or remain as repayable debt.

If the savings target is fully delivered, then the blended WACC is 11.0%, which stands out at a hyper-relative seven percentage points compared to the conventional 18.0%. Scheduled debt-service due to the bank is 13.89 units, so when we add back 1.32 in deferred ESCO remuneration (that the company will avoid paying if it runs out of cash), we have a TFS equal to 15.21 units.

The comparator requires 18.37 units. Against annual savings of 18.7 units, VSCR therefore rises from 1.02 to 1.23. The improvement is not produced by writing off public money at the outset. It follows from longer tenor, lower-cost debt, explicit allocation of implementation risk, and conditional rather than automatic fiscal support.

Table 4. Illustrative capital stack for a 100-unit energy-efficiency project

Financing source	Share	Illustrative cost / term	Economic role
Sponsor equity	15%	18% required return	Alignment and first-loss commitment
Commercial bank debt	45%	14%; 7 years	Main repayable domestic financing
Concessional debt	25%	6%; 10 years	Longer tenor and lower blended cost
Performance-linked public tranche	10%	0%; 5 years; 2-year grace; subordinated; converts after verification	Conditional fiscal support linked to verified physical savings
ESCO deferred remuneration	5%	10%; 5 years; included in TFS	Transfers part of implementation risk
Partial public guarantee	20% of commercial bank principal; outside capital stack	Maximum exposure 9 units; zero fee in synthetic base case	Reduces lender loss; treated as contingent support, not upfront cash

Figure 4.

Calculated outcome: WACC 11.0%; annual bank-debt service 13.89 units; TFS 15.21 units; conventional financing service 18.37 units. The transaction mobilizes 4.74 units of non-budget capital and 3.42 units of private-commercial capital per unit of committed public support; cash-outlay leverage is 9.00 if the guarantee is not called.

3.3. Savings-realization sensitivity

The value of the gate becomes clearest when actual performance departs from the contract. At $qE = 0.70$, monetized verified savings are 13.09 units, below TFS; VSCR is 0.86 and the base rule authorizes no conversion. At $qE = 0.85$, savings cover financing service only narrowly (VSCR 1.05), and one half of the public tranche converts. Full conversion is reserved for qE of at least 1.00. Because tariffs can change independently of engineering performance, qE is calculated in physical units, whereas VSCR remains a monetary test of repayment capacity.

Table 5. Sensitivity of financing performance to verified physical energy savings

Verified physical savings, qE	Monetized verified savings	VSCR (MVS / TFS)	Grant-conversion factor at $L=70\%$	Required response
70%	13.09	0.86	0.00	No grant conversion; diagnose underperformance and restructure
85%	15.90	1.05	0.50	Partial conversion; corrective plan and closer monitoring
100%	18.70	1.23	1.00	Full result-linked release; normal repayment
115%	21.51	1.41	1.00	Full release; possible shared-savings bonus and replication

Figure 5.

Table 6. Sensitivity of grant conversion to the provisional lower threshold

Verified physical savings qE	Lower threshold $L=60\%$	Lower threshold $L=70\%$	Lower threshold $L=80\%$
70%	0.25	0.00	0.00
85%	0.625	0.50	0.25
100%	1.00	1.00	1.00

Figure 6.

At $qE = 0.85$, the converted share is highly sensitive to the policy threshold: 0.625 when $L = 0.60$, 0.50 when $L = 0.70$, and

0.25 when $L = 0.80$. The threshold is therefore not a technical constant. It is a fiscal choice that should reflect the technology, the expected dispersion of project performance, and the precision of the M&V method.

VSCR uses monetized verified savings and TFS of 15.21 units. Grant conversion uses normalized physical savings qE . The distinction prevents tariff movements from determining the amount of fiscal support; all thresholds remain provisional until calibrated on an actual portfolio.

Figure 1. Verification-gated blended finance waterfall

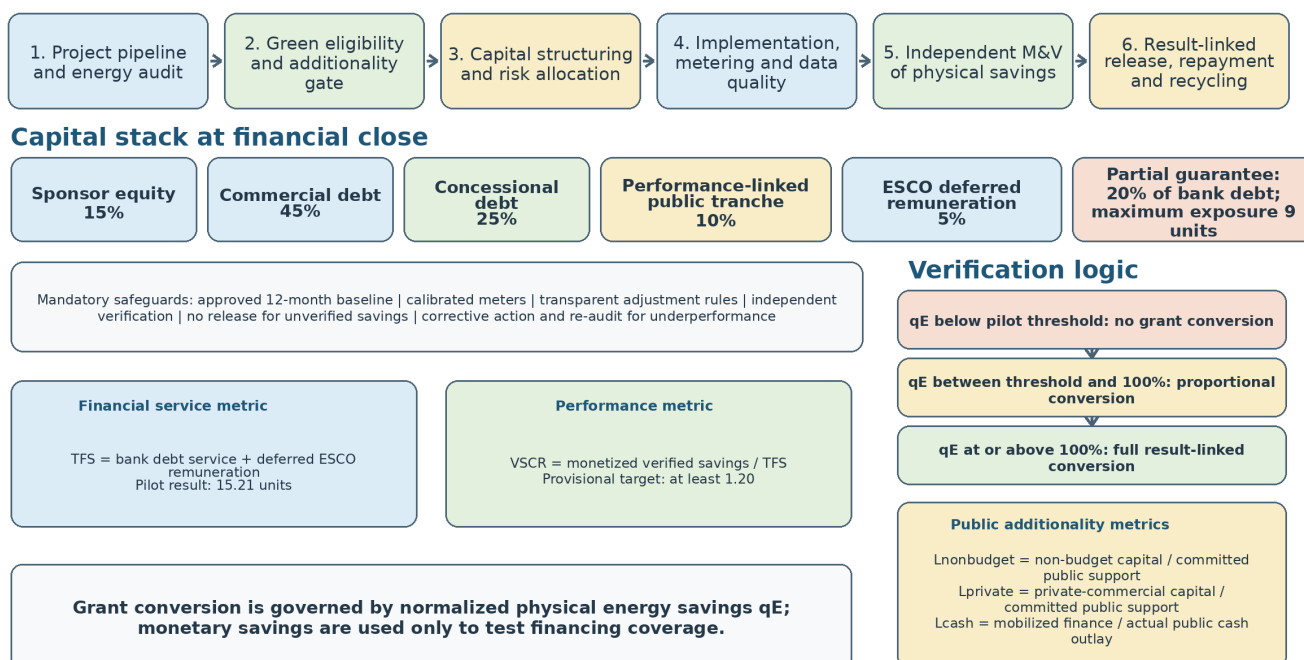


Figure 7.

Source: developed by the author.

3.4. Institutional responsibilities

The institutional design separates those who deliver performance from those who verify it or bear credit risk. Procurement, operations, data access and scheduled payments are controlled by the project owner. Under the savings obligation, the ESCO or contractor designs, installs, commissions and rectifies the intervention. The commercial bank evaluates the borrower and manages the debt without determining whether the public portion has merit to conversion. Development financiers provide medium- and long-term capital, technical assistance, and template documents. It prescribes the eligibility, fixes the guarantee, records contingent liabilities and sanctions output-linked benefit. Baseline, metering, normalization, physical savings and uncertainty are all reviewed by an independent verifier following recognized M&V principles [19,20].

Table 7. Institutional allocation of responsibilities

Actor	Primary responsibility	Key control	Recorded output
Project owner	Procurement, access, operations, and scheduled financing service	No unilateral baseline change	Operating data and payment record
Energy-service company (ESCO) / contractor	Design, installation, commissioning, savings guarantee	Performance liability and correction duty	Commissioning file and corrective actions
Commercial bank	Credit appraisal, disbursement, bank-debt monitoring, and restructuring	Separate borrower risk from technical performance risk	Loan file and covenant report
Development financier	Concessional tranche, technical assistance, standardization	Additionality and crowding-in test	Financing agreement and project-preparation record
Public authority / guarantee fund	Eligibility, guarantee cap, result-linked support	No grant conversion without independent verification; record contingent exposure	Support decision and fiscal exposure register
Independent verifier	Baseline review, metering, normalization, physical-savings confirmation, and uncertainty assessment	Conflict-of-interest and evidence standards	M&V report, uncertainty statement, and verified-savings certificate

Figure 8.

Table 8. Minimum measurement and verification protocol for a pilot transaction

M&V element	Provisional pilot specification	Control purpose
Method boundary	IPMVP Option B for isolated equipment; Option C for whole facilities	Match evidence to project design
Baseline period	Normally at least 12 continuous months	Capture seasonality and operating patterns
Adjustment variables	Weather, production, occupancy, operating hours, water delivery, and material non-routine events	Prevent artificial savings
Metering and data quality	Calibrated meters; documented frequency; provisional completeness target at least 90%	Ensure traceable and usable data
Uncertainty rule	Report confidence and relative precision; use a conservative lower bound for grant conversion when material	Protect public funds from measurement noise
Missing data and disputes	Pre-agreed substitution hierarchy, materiality limit, independent second review, and correction window	Create reproducible remedies

Figure 9.

4. Discussion

The major contribution of the proposed waterfall is in the timing of fiscal commitment. Public financial institutions, guarantees and concessional instruments have been shown by the literature to mobilise investment when taking risks that markets are risk averse about or hydrophobically unable to absorb, [4-8]. In the current model, a more stringent transaction rule has been added: public support is non-repayable only after there is evidence that the relevant output—normalized energy savings—has been achieved. Avoided outlay is also more anecdotally transparent and less-stably contractually-backed than income through a power-purchase agreement, which is important.

And this romance rule also renders additionality testable. Public support is defensible only when it alters the feasibility or tenor, eliminates a binding financing cost, or mobilizes capital that would be otherwise locked out. Who purchased a qualifying technology is not enough to justify it. This is a more robust structure than defining an a priori charge mix since the transaction leaves an audit trail of two dichotomous facts, one if public money was needed at financial close and another as to whether it paid for measurable performance ex post. This rationale is in accordance with blended-finance principles on minimum concessionality, commercial sustainability, crowding-in and governance [7,8].

M&V is part of financial control rather than an engineering appendix in this structure. A weak baseline, missing or uncalibrated meters through to changes in production or occupancy and even extreme weather all have the ability to vary the computed saving sufficiently enough to change both VSCR as well as the fiscal payment. Hence, the M&V plan is required to be agreed upon contractually pre-financial close and consists of determining the measurement boundary [18],

baseline period, adjustment variables, data frequency [19], quality standards, uncertainty rule [20], verifier independence and dispute process. Physical savings (net) + grant conversion = monetary savings; monetary savings to revenue ratio rating (adjusted for tariff differences). Then a tariff increase, plus the grant to get larger without higher energy performance.

The 70% scenario is a good example of why the generalized public response to underperformance matters — it be diagnostic, rather than automatic. The target level of verified savings is no longer sufficient to cover the contracted financing. At the same time, raising the grant would mask rather than cure this underlying source of shortfall. This helps parties establish whether the issue stemmed from equipment failure, operating practice, an incorrect baseline, changed production, missing data or a maintenance shortfall. The response may then be matched to the evidence: repairing and recommissioning, recording a case-specific set of adjustments in outturns, enhanced scrutiny, rescheduling debt repayments or recovering the unexchanged public tranche.

There are a number of credible pilot contexts within Uzbekistan. Public buildings, hospitals, schools, pumping stations, district-heating networks and municipal lighting tend to consist of a high saving potential and low upfront budgets. This waterfall could connect foreign budget support, domestic bank credit in line with development finance, a partial guarantee of either design or consumption, and ESCO performance obligations while retaining municipal recourse to fiscal court against the delivery vector until results are verified. That principle applies in support of industrial modernization where energy use is reduced making competitive industries even more competitive. However, it should not be mechanically passed onto stand-alone renewable generation for which, by virtue of the fact it does produce electricity, verifiable output is the proper performance base — not avoided consumption.

Neither should a one size fits all be applied to all sectors Industrial work requires normalization of baselines for delivery, as well as a more robust connection to the credit risk of the counterparty. Procurement and budget-payment systems for public buildings must be enforceable. District heating itself needs to be weather-normalized, and irrigation depends both on seasonally delivered water resources but also electricity usage. Pilot portfolios would thus combine sector-specific tenors, thresholds, and M&V rules with a common fiscal principle: no repayment-free support without independently verified physical performance.

The pure numbers should be interpreted as a test of the design, not an estimate of system-wide effects. Default probability is not modeled and completed Uzbek project portfolios are not used; rates, fees, tranche terms, transaction costs and savings are all assumed values. Simplification of foreign-exchange exposure, inflation, taxes, tariff reform, M&V expense and accounting for grant conversion. An empirical step that compares three or more project types and reports distributions of a number of parameters, including verified savings, verifier cross-verification per each independently validated unit of energy saved (called guarantee calls), repayment performance by project type/scale, mobilized private capital, total transaction cost and fiscal cost/unit. Before the provisional threshold can be used in a policy context, those observations are required.

Conclusion

The article operationalizes a high-level blended-finance concept as a concrete rule for how environmental bankable policy action can be framed or ruled out based on low-cost access to capital in the Domestically-Driven Transition (DDT) finance regime that exists and is forthcoming in Uzbekistan. Eligibility for green, readiness for financing, evidence of installation, savings in physical and fiscal quantity are evaluated at various measures. What is key to the contract is that the publicly subordinated tranche should only be recoverable at entry, and earns grant status only to the extent validated independent of it.

This is what leads us to a synthetic 100 unit case to show the economic effect of those assumptions. Blending decreases WACC from 18.0% to 11.0%, cuts scheduled fee service from 18.37 to fifteen.21 units, and increases VSCR from 1.02 to at least one.23 when the contracted saving is achieved At 70% physical realization, VSCR drops at 0.86 and the base rule disallows conversion. So it enhances affordability without sacrificing discipline—fiscal support is conditional, trackable, and clawed back when results are lacking.

Next up is not a uniform rollout, but instead a smaller pilot that produces data. Public buildings, industrial modernization, irrigation and district heating need to be tested as separate portfolios. They each require precise tranche and guarantee parameters with an approved baseline, the applicable IPMVP option, meter & data standards, an uncertainty rule, independent verification for issuance of the bond itself (this is also a key corrective-action mechanism), conversion formula, accounting treatment and recycling repayment rules. Evidence of lower all-in financing cost, genuine mobilization of non-budget capital, verified energy savings, sound repayment and controlled fiscal exposure should limit scale-up.

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Conflict of Interest Statement

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Data Availability Statement

The article uses no confidential project or borrower data. Every numerical assumption required to reproduce the synthetic transaction is reported in Tables 1 and 4-6 and in the accompanying workbook, which sets out the capital stack, annuity calculations, WACC, TFS, VSCR, leverage measures, physical-savings scenarios, and threshold tests. Empirical validation will require access, subject to institutional approval and data-protection rules, to project contracts, approved energy baselines, calibrated meter records, M&V reports, financing-service histories, guarantee registers, and decisions on fiscal support.

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