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ENSURING SUSTAINABLE ECONOMIC DEVELOPMENT OF BUKHARA REGION THROUGH GREEN INVESTMENTS

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Abstract: The article proposes an integrated management model for green investments as a tool for the sustainable economic development of the Bukhara region, comprising a multilevel indicator system, a composite green investment sustainability index, and a decision-oriented monitoring mechanism. An analysis of current practices in attracting and evaluating investments identifies four areas requiring further improvement: fragmented accounting of green projects, insufficient alignment between environmental and economic goals, limited applicability of national indicators at the regional level, and the need for a clearer link between measurement and managerial decisions. Based on these findings, four requirements for an improved system are formulated, and a three-layer architecture is proposed, covering fifteen indicators across five blocks: renewable energy and energy efficiency; water resources and irrigation; green agriculture and waste management; industry and green infrastructure; and financial mechanisms and human capital. The composite index is constructed using linear min–max normalization and a weighted geometric mean with differentiated weights; its dynamics are illustrated using indicative estimates for 2018-2025.

Key words: green investment, sustainable development, Bukhara region, green economy, composite index, renewable energy, regional governance, monitoring system.

Аннотация: В статье предлагается интегральная модель управления зелёными инвестициями как инструментом устойчивого экономического развития Бухарской области, включающая многоуровневую систему индикаторов, композитный индекс устойчивости зелёных инвестиций и механизм мониторинга, ориентированный на принятие управленческих решений. Анализ современной практики привлечения и оценки инвестиций позволил выявить четыре направления, требующих дальнейшего совершенствования: фрагментарный учёт зелёных проектов, недостаточную согласованность экологических и экономических целей, ограниченную применимость национальных показателей на региональном уровне и необходимость установления более чёткой связи между измерением показателей и принятием управленческих решений. На основе полученных результатов сформулированы четыре требования к усовершенствованной системе и предложена трёхуровневая архитектура, охватывающая пятнадцать показателей, объединённых в пять блоков: возобновляемая энергетика и энергоэффективность; водные ресурсы и орошение; зелёное сельское хозяйство и обращение с отходами; промышленность и зелёная инфраструктура; финансовые механизмы и человеческий капитал. Композитный индекс рассчитывается на основе линейной min–max-нормализации и взвешенного геометрического среднего с дифференцированными весами; его динамика проиллюстрирована ориентировочными оценками за 2018-2025 гг.

Ключевые слова: зелёные инвестиции, устойчивое развитие, Бухарская область, зелёная экономика, композитный индекс, возобновляемая энергетика, региональное управление, система мониторинга.

INTRODUCTION

The Bukhara region faces an important development challenge: increasing incomes and employment while simultaneously reducing pressure on water resources, soil, and the atmosphere associated with the traditional “take-make-dispose” model. Irrigation water constraints in an arid climate, soil salinisation, the high energy intensity of industry and agriculture, and the significant share of fossil fuels in the energy balance are interconnected challenges rather than isolated technical issues. These challenges reflect an approach in which regional development continues to be assessed primarily through output volumes and the amount of investment absorbed, rather than the extent to which investments improve resource efficiency and the long-term resilience

of the economy. The purpose of this study is to propose an integrated model that brings existing practices of attracting green capital into a unified framework comprising a multilevel indicator system, a methodology for constructing a composite index, and a monitoring mechanism that links measurement to specific managerial responses.

An analysis of how green investments are monitored at the regional level identifies four recurring areas requiring further improvement, which provide the rationale for this study. First, accounting practices remain fragmented: projects in solar energy, water conservation, waste recycling, and energy efficiency are recorded by different agencies using incompatible measurement units, making it difficult to obtain a comprehensive overview at the district or regional level. Second, environmental indicators are not consistently evaluated alongside economic indicators: a project may demonstrate environmental benefits while remaining financially unviable and unable to recover its costs, and vice versa. Third, national and sectoral indicators are calculated at levels of aggregation that limit their practical applicability to decision-making at the district or enterprise level. Nationwide statistics provide limited guidance to a khokimiyat when determining how to allocate available financial resources within the current budget cycle. Fourth, and particularly importantly, evaluation results are not consistently translated into practical action: a low score in water conservation or energy efficiency does not automatically trigger a predefined managerial or policy response, meaning that assessments remain primarily descriptive rather than serving as instruments for corrective action.

LITERATURE REVIEW

The international literature on the green economy provides a useful starting point but requires adaptation to regional conditions. The United Nations Environment Programme (UNEP) concept of a green economy [10], the OECD approach to green growth [8], and the World Bank approach to inclusive green growth [11] establish the general framework linking investment, resource efficiency, and well-being. The OECD handbook on composite indicators [7] defines the requirements for normalisation, weighting, and aggregation. However, these documents were not specifically designed to address the characteristics of an arid Central Asian region that is heavily dependent on irrigation and resource-based sectors.

Research on the circular economy and sustainable agri-food systems [3-5] demonstrates that closing resource loops and reducing losses are integral components of green investment, particularly in agricultural regions. At the national level, the main policy frameworks are the “Uzbekistan-2030” Strategy [1] and the Strategy for the Transition of the Republic of Uzbekistan to a Green Economy for 2019-2030 [2], which establish targets for the share of renewable energy, energy efficiency, and water conservation. Regional characteristics of the development of agro-industrial enterprises in the Bukhara region are examined in [6], while the potential for green economy development in Uzbekistan is analysed in the author’s earlier monograph [9]. Nevertheless, the available sources do not yet provide a unified system that combines regional specificity, a balance between economic and environmental objectives, and a direct link to managerial decision-making; this study aims to address that gap.

RESEARCH METHODOLOGY

Taking the literature and the identified shortcomings into account, four requirements were established for the system.

The first requirement is territorial detail. The system must capture investment flows and their results at the level where actual decisions are made - the district, mahalla, or enterprise - while allowing indicators to be aggregated to the regional and national levels for public policy purposes.

The second requirement is economic–environmental balance. An indicator that ignores costs and payback periods may favour symbolic projects over those that the region can sustain in the long term; conversely, a purely financial perspective does not fully capture the ecological rationale for green investment. Both dimensions must therefore be incorporated into the same evaluation rather than presented in separate reports.

The third requirement is data feasibility. Indicators should be calculable using information that enterprises, khokimiyats, and statistical bodies already collect or can collect at a reasonable cost, ensuring that the system remains manageable in terms of data requirements during the first reporting cycle.

The fourth requirement is decision linkage. Each indicator must have a predefined managerial response specifying who is responsible for taking action, at what threshold, and what type of intervention is expected. This ensures that the evaluation serves as a practical management tool rather than remaining solely an academic exercise.

Guided by these requirements, a three-layer architecture is proposed. The first layer is the basic indicator system, comprising fifteen specific indicators grouped into five blocks (Table 1). The second layer is the

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integration stage, in which normalised block sub-indices are combined into a single weighted composite index. The third layer is managerial, involving the ranking of districts and enterprises, a monitoring calendar, and a decision matrix linking index ranges to specific measures, such as preferential lending for water-saving equipment or targeted extension support.

The composite index is constructed in two steps. First, individual indicators are normalised to a common 0-1 scale using linear min-max normalisation, with boundary values set at the 3rd and 97th percentiles to limit the influence of extreme observations. A small positive constant δ is added to prevent a zero-valued sub-indicator from reducing the geometric mean to zero. Benefit-type indicators (such as the share of renewables) are normalised so that higher values correspond to higher scores, while cost-type indicators (such as the water-loss coefficient or emission intensity) are inverted to ensure a consistent interpretation across the entire index:

$$z_{ij} = (x_{ij} - x_j^{min}) / (x_j^{max} - x_j^{min}) + \delta \quad \text{(benefit-type)}, \qquad (1)$$

$$z_{ij} = (x_j^{max} - x_{ij}) / (x_j^{max} - x_j^{min}) + \delta \quad \text{(cost-type)}, \qquad (2)$$

where x_{ij} represents the value of indicator j for territory (or year) i, while x_j^{min} and x_j^{max} denote the 3rd and 97th percentiles of indicator j, respectively.

Block weights were determined through an expert-analytical procedure that combines each block's contribution to overall sustainability with the significance of the challenges currently observed in the respective areas: energy and energy efficiency - 0.25; water resources and irrigation - 0.25 (given the scale of losses in irrigation networks); agriculture and waste – 0.20; industry and infrastructure - 0.15; and finance and human capital - 0.15. Within each block, indicators are assigned equal weights, as they measure complementary aspects of the same practice, and unequal weighting would imply a level of precision that the available data do not support. Block sub-indices S_k (the equally weighted averages of the normalised indicators in block k) are combined using a weighted geometric mean:

$$GISI = 100 \times \prod_k S_k^{w} \ , \quad \Sigma w_k = 1, \qquad (3)$$

where w_k represents the block weights listed above. The geometric formulation preserves the "weakest-link" property: a block with relatively lower performance reduces the overall index more substantially than a simple arithmetic average would, thereby encouraging balanced improvements across all blocks rather than prioritising excellence in one area while other areas receive less attention.

ANALYSIS AND RESULTS

The proposed indicator system is summarised in Table 1. Three principles guided its construction: each indicator should point to a distinct, manageable practice rather than restate a related measure; indicators within a block should complement rather than duplicate one another; and the data source and collection frequency should be stated clearly enough that a district office could begin collecting the series without further guidance (table 1).

Table 1. Indicator system for assessing green investment in Bukhara region[1]

Block	Key indicators	Data source	Periodicity
Renewable energy and energy efficiency	Share of renewables in electricity consumption; energy intensity of gross regional product; share of facilities that have undergone an energy audit	Energy supply organisations, statistics	Annual
Water resources and irrigation	Share of areas using water-saving irrigation technologies; loss coefficient in delivery networks; water productivity per hectare	Water-user associations, meter data	Seasonal / annual
Green agriculture and waste	Share of waste recycled; share of organic farming; volume of composting and biogas units	Farm reports, agricultural statistics	Annual
Industry and green infrastructure	Share of enterprises with certified environmental management systems; emissions per unit of output; area of green plantings	Environmental authorities, statistics	Annual
Financial mechanisms and human capital	Volume of green loans and grants; share of private investment in green projects; number of trained specialists	Banks, khokimiyat, educational institutions	Annual

1 Author's development.

In the energy block, it is important to monitor the share of renewable energy generation separately from the energy intensity of the economy. The region can expand solar capacity without necessarily reducing energy consumption per unit of output, and assessing both indicators together helps determine whether investment should be directed towards new generation capacity or the modernisation of energy-consuming sectors. The water block distinguishes between the adoption of water-saving technologies and the water-loss coefficient in irrigation networks. A district may expand drip irrigation while still experiencing substantial water losses during transportation. Considering both indicators together helps identify priority areas for financing, whether the introduction of new irrigation technologies or the rehabilitation of canals.

The agricultural block evaluates waste recycling separately from the share of organic farming, as a farm may demonstrate stronger performance in one area while having further opportunities for improvement in the other. The industry and infrastructure block presents particular challenges in defining indicators because environmental management systems among the region's enterprises are at different stages of development. The indicators were selected based on the availability of at least partial records, thereby keeping the reporting burden manageable. Finally, the financial block links the volume of green lending to the share of private capital, making it possible to assess whether a sustainable green investment market is emerging or whether projects continue to depend on budgetary support.

Table 2 presents indicative estimates of the equally weighted and differentially weighted versions of the index for 2018-2025. These values are illustrative and should be replaced with actual calculations based on data from the regional statistics department and relevant agencies (table 2).

Table 2. Dynamics of the green investment sustainability index of Bukhara region (indicative)[2]

Year	Equal-weight index	Weighted index (proposed method)	Remarks
2018	36.2	34.8	Baseline year; traditional sectors dominate
2019	39.5	37.9	National green economy transition strategy adopted
2020	41.8	39.9	Pandemic slowed implementation of investment programmes
2021	45.3	43.6	Recovery; water-saving irrigation expanded
2022	49.7	47.5	Growth in the number of solar installations across districts
2023	53.4	50.6	Green lending mechanisms launched
2024	57.6	54.0	Higher share of private investment
2025	61.2	56.7	Water losses in networks still constrain the index

The weighted index follows the equal-weight series fairly closely but remains consistently slightly lower, reflecting the greater weight assigned to the water block, where the loss coefficient has improved more slowly than the other indicators. The 2025 estimate illustrates how the results are intended to be interpreted in practice: the energy block reached the high-performance range due to the expansion of renewable energy capacity; the water block remained in the medium-performance range, reflecting continued network losses despite the increasing adoption of water-saving technologies; the agricultural block demonstrated progress through the development of waste recycling; and the industry and infrastructure block, along with the financial block, remained the areas with the greatest potential for further improvement, reflecting the relatively early stage of development of the corresponding mechanisms. The weighted index of 56.7 was noticeably lower than the equal-weight figure of 61.2, indicating that the water and financial blocks should receive priority in the next round of targeted investments rather than adopting a broad, undifferentiated approach across all five areas.

The managerial layer of the model incorporates a decision matrix. When a block sub-index falls below 40 points, a targeted regional-level programme is initiated (for example, the reconstruction of irrigation networks). Within the 40-60-point range, district-level measures are implemented (extension support and preferential loans). Above 60 points, the achieved results are consolidated, and successful practices are replicated in other districts. The threshold values are subject to further refinement as additional data become available.

CONCLUSIONS AND RECOMMENDATIONS

The study proposes an integrated model for managing green investments to ensure the sustainable economic development of the Bukhara region, combining a five-block indicator architecture, a normalisation and weighting method for constructing a composite index, and a managerial layer that links index value ranges

2 Author's development.

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to specific measures. The indicative estimates for 2018-2025 demonstrate a plausible and improving trajectory while also identifying areas requiring further development, primarily the reduction of water losses in irrigation networks and the improvement of emerging mechanisms for private green financing.

The main value of the model lies not only in the composite score itself but also in its ability to provide a detailed assessment: a district office or enterprise manager can trace a value requiring improvement back to the relevant block or individual indicator and link it to a predefined managerial response. Based on the findings of the study, the following measures are proposed:

1. To establish a unified database of green projects at the regional khokimiyat level, using standardised units of measurement and clearly defined data sources.
2. To approve the indicator system (Table 1) and the composite index as official tools for annual monitoring across the districts of the region.
3. To prioritise the allocation of budgetary and attracted funds to the blocks with the lowest sub-index values, particularly water conservation, the reconstruction of irrigation networks, and the development of green lending.
4. To develop incentive mechanisms for private investors, including preferential lending, tax and customs preferences, guarantees for green projects, and public–private partnerships.
5. To organise training and retraining programmes for personnel in the field of the green economy in cooperation with the region's universities.
6. In further research, to replace the illustrative data with actual data, calibrate the block weights with the participation of experts, and pilot the model in selected districts of the region.

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