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Improving methods for assessing and managing the green-economy adaptability of textile enterprises

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ABSTRACT

This article develops an organizational-economic approach to assessing and managing the adaptability of textile enterprises to the green economy. The study is motivated by the resource-intensive nature of textile production and by Uzbekistan's policy objectives for green transformation, including a minimum 20% increase in industrial energy efficiency, a 30% reduction in energy intensity per unit of GDP, and a 35% reduction in greenhouse-gas intensity relative to the 2010 level by 2030. Using comparative analysis, indicator normalization, geometric aggregation and management diagnostics, the paper proposes a Green Adaptability Index (I_{green}) that integrates four dimensions: energy efficiency, water efficiency, waste circularity and green-technology readiness. The index is designed as a management instrument rather than as a substitute for environmental auditing: it identifies bottlenecks, supports inter-period and inter-enterprise comparison, and links resource-saving measures to production-potential management. A system of measurable indicators and threshold-based interpretation is presented. The paper also develops a five-stage management cycle—measurement, normalization, index calculation, bottleneck identification, and corrective monitoring-and discusses how renewable energy, water reuse, cleaner production, circular material flows and digital resource metering can strengthen the resilience and competitiveness of textile enterprises. The proposed framework is particularly suitable for enterprise-level application once primary data on electricity, fuel, water, waste, recycled materials, renewable-energy generation and green investment are available.

Keywords: green economy, textile industry, green adaptability, production potential, energy efficiency, water efficiency, circular economy, waste management, green technology, resource efficiency.

Совершенствование методики оценки и управления адаптируемостью текстильных предприятий к условиям зеленой экономики

АННОТАЦИЯ

В статье разработан организационно-экономический подход к оценке и управлению адаптивностью предприятий текстильной промышленности к условиям зелёной экономики. Актуальность исследования обусловлена высокой ресурсоёмкостью текстильного производства, а также

Ключевые слова: зелёная экономика, текстильная промышленность, зелёная адаптивность, производственный

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стратегическими целями Узбекистана в области зелёной трансформации, предусматривающими к 2030 году повышение энергоэффективности промышленности не менее чем на 20%, снижение энергоёмкости на единицу ВВП на 30% и сокращение интенсивности выбросов парниковых газов на 35% по сравнению с уровнем 2010 года. На основе сравнительного анализа, нормализации показателей, геометрического агрегирования и управленческой диагностики предложен индекс зелёной адаптивности (I_{green}), объединяющий четыре основных направления: энергоэффективность, эффективность использования водных ресурсов, циркулярность отходов и готовность к внедрению зелёных технологий. Предлагаемый индекс рассматривается как инструмент управления, а не как замена экологического аудита: он позволяет выявлять проблемные направления, проводить межпериодные и межфирменные сопоставления, а также связывать ресурсосберегающие мероприятия с управлением производственным потенциалом предприятия. Разработана система измеримых показателей и предложена их пороговая интерпретация. Кроме того, сформирован пятиэтапный цикл управления, включающий измерение показателей, их нормализацию, расчёт индекса, выявление проблемных направлений и корректирующий мониторинг. Обосновано, что использование возобновляемых источников энергии, повторное использование воды, внедрение более чистых производственных технологий, формирование циркулярных потоков материальных ресурсов и цифровой учёт потребления ресурсов способствуют повышению устойчивости и конкурентоспособности текстильных предприятий. Предлагаемый методический подход может быть применён на уровне отдельных предприятий при наличии первичных данных о потреблении электроэнергии, топлива и воды, образовании и переработке отходов, использовании вторичных материалов, производстве энергии из возобновляемых источников и объёмах зелёных инвестиций.

потенциал, энергоэффективность, эффективность использования водных ресурсов, циркулярная экономика, управление отходами, зелёные технологии, ресурсоэффективность.

To‘qimachilik korxonalarining yashil iqtisodiyotga moslashuvchanligini baholash va boshqarish uslublarini takomillashtirish

ANNOTATSIYA

Mazkur maqolada to‘qimachilik sanoati korxonalarining yashil iqtisodiyot sharoitlariga moslashuvchanligini baholash va boshqarishning tashkiliy-iqtisodiy yondashuvi ishlab chiqilgan. Tadqiqotning dolzarbligi to‘qimachilik ishlab chiqarishining yuqori resurs sig‘imiga egaligi, shuningdek, O‘zbekistonda yashil transformatsiya bo‘yicha belgilangan strategik maqsadlar bilan izohlanadi. Ushbu maqsadlar 2030-yilga qadar sanoatda energiya samaradorligini kamida 20 foizga oshirish, yalpi ichki mahsulot birligiga to‘g‘ri keladigan energiya sig‘imini 30 foizga kamaytirish hamda issiqxona gazlari emissiyasi intensivligini 2010-yil darajasiga

Kalit so‘zlar:
yashil iqtisodiyot, to‘qimachilik sanoati, yashil moslashuvchanlik, ishlab chiqarish salohiyati, energiya samaradorligi, suv resurslaridan foydalanish samaradorligi, sirkulyar iqtisodiyot, chiqindilarni boshqarish, yashil

nisbatan 35 foizga qisqartirishni nazarda tutadi. Qiyosiy tahlil, koʻrsatkichlarni normallashtirish, geometrik agregatsiyalash va boshqaruv diagnostikasi usullaridan foydalanish asosida toʻrtta asosiy yoʻnalishni - energiya samaradorligi, suv resurslaridan foydalanish samaradorligi, chiqindilarning sirkulyarligi va yashil texnologiyalarni joriy etishga tayyorlikni birlashtiruvchi Yashil moslashuvchanlik indeksi (I_{green}) taklif etilgan. Mazkur indeks ekologik auditning oʻrnini bosuvchi vosita sifatida emas, balki korxona boshqaruvining diagnostik instrumenti sifatida ishlab chiqilgan. U korxona faoliyatidagi muammoli yoʻnalishlarni aniqlash, turli davrlar va korxonalar kesimida qiyosiy baholashni amalga oshirish hamda resurslarni tejashga qaratilgan chora-tadbirlarni ishlab chiqarish salohiyatini boshqarish jarayoni bilan oʻzaro bogʻlash imkonini beradi. Tadqiqot doirasida oʻlchanadigan koʻrsatkichlar tizimi shakllantirilib, ularni chegaraviy mezonlar asosida talqin qilish usuli taklif etilgan. Shuningdek, koʻrsatkichlarni oʻlchash, normallashtirish, indeksni hisoblash, muammoli yoʻnalishlarni aniqlash va tuzatuvchi monitoringni amalga oshirishdan iborat besh bosqichli boshqaruv sikli ishlab chiqilgan. Qayta tiklanuvchi energiya manbalaridan foydalanish, suvdan takroriy foydalanish, toza ishlab chiqarish texnologiyalarini joriy etish, materiallarning aylanma oqimini shakllantirish hamda resurslar sarfini raqamli hisobga olish toʻqimachilik korxonalarining barqarorligi va raqobatbardoshligini oshirishga xizmat qilishi asoslangan. Taklif etilgan uslubiy yondashuv elektr energiyasi, yoqilgʻi, suv sarfi, chiqindilar hajmi va ularni qayta ishlash, ikkilamchi materiallardan foydalanish, qayta tiklanuvchi energiya ishlab chiqarish hamda yashil investitsiyalar hajmi toʻgʻrisidagi birlamchi maʼlumotlar mavjud boʻlgan sharoitda alohida toʻqimachilik korxonalari faoliyatini baholashda qoʻllanilishi mumkin.

texnologiyalar, resurs samaradorligi

INTRODUCTION

The transition from a resource-intensive growth model to a green economy is increasingly becoming a strategic condition for industrial competitiveness. For textile enterprises, this transition is especially important because production chains combine energy-consuming mechanical processes with water- and chemical-intensive wet processing, while garment production also generates substantial cutting and post-industrial waste. Contemporary sustainability research therefore treats energy, water, materials, emissions and circularity as interrelated dimensions of textile-sector transformation [2–5].

In Uzbekistan, the policy framework has moved green transformation from a general environmental objective to a measurable economic agenda. The national programme for transition to a green economy by 2030 sets targets that include increasing industrial energy efficiency by at least 20%, reducing energy consumption per unit of GDP by 30%, reducing greenhouse-gas intensity by 35% from the 2010 level, and expanding renewable-energy capacity and resource-saving practices [1]. The 2025 State Programme further emphasizes decarbonization, energy-saving equipment, renewable energy, online environmental monitoring and the application of circular-economy principles in enterprises [6].

For textile enterprises, these objectives create a managerial problem: conventional production-potential indicators—capacity, output, labour and capital productivity—do not fully show how prepared an enterprise is to operate under tighter resource, environmental and market requirements. A firm may have high installed capacity but remain vulnerable because of excessive energy intensity, high water consumption, low waste recovery or insufficient investment in cleaner technology. Therefore, green adaptability should be assessed as a specific capability of production-potential management.

Previous research has examined life-cycle thinking, circular economy, textile waste recovery, sustainable wet processing and water sustainability [2–5, 7]. However, enterprise managers also require a compact diagnostic indicator that can combine heterogeneous resource-efficiency measures and reveal the weakest dimension of green transformation. The purpose of this study is therefore to develop a methodological framework for assessing the green-economy adaptability of textile enterprises and to propose a management mechanism based on an integrated Green Adaptability Index.

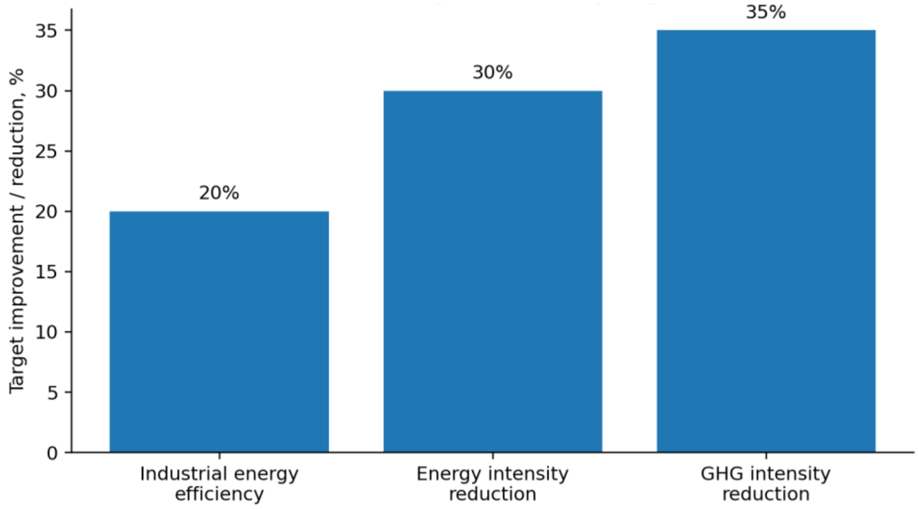

Figure 1. Selected green-economy targets of Uzbekistan to 2030. Source: compiled by the author based on the national green-economy programme [1].

2. MATERIALS AND METHODS

2.1. Research design and indicator system

The study applies a methodological and analytical design based on official policy targets and established cleaner-production and textile-sustainability approaches. The proposed model is intended for subsequent empirical application to textile enterprises using annual or quarterly primary data. Four dimensions are selected because they capture the main resource and technological channels through which a textile enterprise adapts to green-economy requirements: energy efficiency, water efficiency, waste circularity and green-technology readiness.

To ensure comparability between indicators expressed in different units, each indicator is normalized to a dimensionless interval from 0 to 1. For a stimulant indicator, where a higher value represents better green performance, min-max normalization is applied:

$$Z_{ij} = \frac{X_{ij} - X_j,min}{X_j,max - x_j,min} \qquad (1)$$

where z_{ij} is the normalized value of indicator j for enterprise i; x_{ij} is the observed value; x_j,min and x_j,max are the minimum and maximum benchmark values.

For a destimulant indicator, where a lower value indicates better performance (for example, kWh per unit of output or m³ of water per tonne of fabric), the transformation is:

$$Z_{ij} = \frac{X_j max - X_{ij}}{X_j,max - x_j,min} \qquad (2)$$

Table 1.

Proposed indicator system for assessing green adaptability of textile enterprises. Source: developed by the author.

Dimension	Recommended enterprise indicator	Direction	Management meaning
Energy efficiency	Electricity/fuel use per unit of output; renewable-energy share	Lower intensity / higher renewable share	Ability to reduce energy cost and carbon exposure
Water efficiency	Water use per unit of output; water-reuse ratio	Lower intensity / higher reuse	Ability to operate under water constraints
Waste circularity	Recovered/recycled textile waste as share of total waste	Higher	Ability to close material loops
Green technology	Share of green investment; energy/water metering; cleaner technologies	Higher	Readiness for technological green transformation

2.2. Construction of the Green Adaptability Index

After normalization, dimension-level sub-indices are calculated as arithmetic means of the indicators included in each block. Let I_energy, I_water, I_waste and I_tech denote the four sub-indices. The integrated Green Adaptability Index is proposed as a geometric mean:

$$I_{green} = \sqrt[4]{Ienergy \times Iwoter \times Iwaste \times Ttech} \qquad (2)$$

The geometric form is preferred because it limits full compensation between dimensions. In other words, very strong performance in renewable energy cannot completely offset extremely weak water efficiency or waste circularity. This property is useful for management diagnostics because green transformation is constrained by its weakest resource or technological component.

For a more differentiated model, weights may be introduced:

$$I_{green} = I_{energy} w1 \times I_{woterw2} \times I_{wastew3} \times I_{techw4}, \qquad \sum wk = 1$$

Weights may be determined by expert assessment, the Analytic Hierarchy Process, entropy weighting, or enterprise strategy. In the absence of validated enterprise-specific weights, equal weights are recommended to avoid artificial precision.

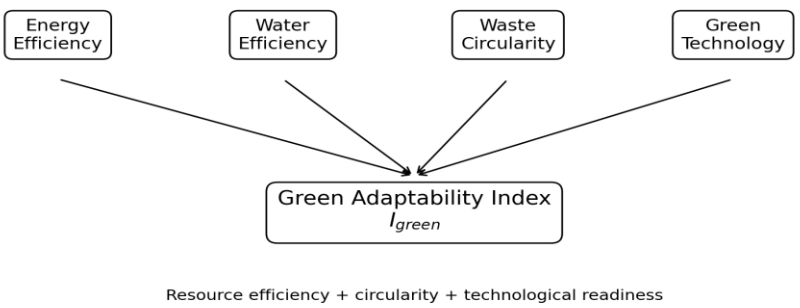

Figure 2. Architecture of the proposed Green Adaptability Index. Source: developed by the author.

2.3. Supporting resource-efficiency coefficients

For practical enterprise diagnostics, the following coefficients can be calculated directly from accounting and production records:

$$E_{int} = E/Q \qquad (2)$$

where E_int is energy intensity, E is total energy consumption in kWh-equivalent, and Q is physical output or value added.

$$W_{int} = W/Q \quad (3)$$

where W_{int} is water intensity and W is total freshwater withdrawal.

$$R_{woter} = W_{reused}/W_{total} \times 100 \quad (4)$$

where R_{water} is the water-reuse ratio.

$$C_{waste} = M_{recycled}/M_{waste} \times 100 \quad (5)$$

where C_{waste} is the waste-circularity coefficient, $M_{recycled}$ is waste returned to reuse/recycling, and M_{waste} is total generated textile waste.

$$R_{RE} = E_{RE}/E_{total} \times 100 \quad (6)$$

where R_{RE} is the share of renewable energy in total enterprise energy consumption.

3. RESULTS

The principal result of the study is a structured assessment mechanism that converts heterogeneous green-performance data into a single diagnostic scale without losing the information contained in the four component sub-indices. This is important because textile sustainability cannot be reduced to one environmental variable. Sustainable wet processing, for example, requires simultaneous reductions in water, chemicals and energy, while circular-economy practices require material recovery, reuse and recycling across the product and production life cycle [3–5].

Table 2.

Proposed interpretation scale for the Green Adaptability Index

I_{green} interval	Adaptability level	Interpretation	Recommended management response
0.80–1.00	High	Resource-efficient and technologically prepared	Maintain performance; scale green innovation
0.60–0.79	Sufficient	Core green practices exist, but gaps remain	Target the weakest sub-index
0.40–0.59	Moderate	Partial adaptation; significant resource losses	Prepare a phased green-modernization programme
0.20–0.39	Low	High exposure to energy/water/waste risks	Priority investment and operational redesign
0.00–0.19	Critical	Green requirements are largely unmet	Comprehensive transformation and external technical support

Source: developed by the author.

The threshold scale should be treated as a managerial classification rather than a universal regulatory standard. Its main purpose is to support comparison across periods and enterprises after a consistent normalization benchmark has been selected. The diagnostic value of the index lies in the simultaneous presentation of I_{green} and its components. For example, an enterprise with I_{green} = 0.67 may be classified as sufficiently adaptable, but if I_{water} = 0.35, management should prioritize water metering, reuse, closed-loop processes and wet-processing modernization rather than distribute investment evenly across all dimensions.

This approach is consistent with cleaner-production logic, which prioritizes reducing raw-material and energy inputs and minimizing waste and emissions at source [8]. It is also compatible with circular-economy research emphasizing waste reduction, material circulation and recovery of value from textile waste [4, 5].

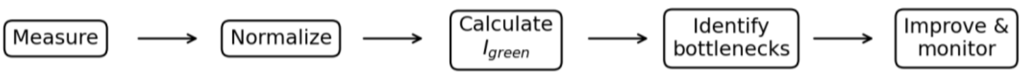

Figure 3. Proposed management cycle for green adaptability. Source: developed by the author.

Table 3.

Management instruments linked to Green Adaptability Index bottlenecks

Identified bottleneck	Management instrument	Enterprise data required	Expected economic/environmental effect
High energy intensity	Energy audit, efficient motors, heat recovery, renewable generation	kWh, fuel, output, peak load	Lower unit energy cost and emissions
High water intensity	Flow metering, counter-current washing, reuse and treatment	m^3 water, output, reused water	Lower freshwater withdrawal and wastewater volume
Low waste circularity	Cutting optimization, segregation, recycling contracts, industrial symbiosis	Waste by type, recycled/reused mass	Lower disposal cost and virgin-material demand
Low green-technology readiness	Green CAPEX plan, digital metering, cleaner-production projects	CAPEX, equipment age, monitoring coverage	Faster adaptation and improved resource control
Weak staff capability	Green skills training and KPI integration	training hours, competency matrix	Improved implementation discipline

Source: developed by the author.

DISCUSSION

The proposed framework has three managerial advantages. First, it links environmental performance to production-potential management. Energy, water and materials are not external environmental variables; they are production resources whose inefficient use increases unit cost and reduces the enterprise’s capacity to compete under changing market requirements. UNIDO’s cleaner-production approach similarly emphasizes preventive resource productivity rather than end-of-pipe control alone [8].

Second, the model reflects the specific structure of textile production. Spinning, weaving, knitting, dyeing, finishing and garment manufacturing have different resource profiles. Wet processing is particularly water- and chemical-intensive, while spinning and weaving may be dominated by electricity consumption. Therefore, enterprise-level benchmarking should use process-appropriate denominators and should not mechanically compare unlike production stages [3].

Third, green adaptability should be interpreted dynamically. Uzbekistan’s green-economy programme explicitly links industrial development to higher energy efficiency, renewable energy and resource saving [1, 6]. Consequently, a textile enterprise that does not improve its resource productivity may face rising relative costs even if its current production volume remains high. Conversely, investments in metering, renewable energy, water reuse, waste recovery and cleaner technologies can strengthen both environmental performance and economic resilience.

The index also has methodological limitations. It does not replace life-cycle assessment, carbon accounting, environmental impact assessment or certified energy audits. Results depend on the quality of primary enterprise data and on the selected normalization benchmarks. For this reason, the next empirical stage should use verified data from comparable textile enterprises over several years and should conduct sensitivity analysis for alternative weighting schemes.

An important extension is the integration of human capital into green transformation. The ILO notes that technological and sustainability transitions in textiles require skills development and lifelong learning [9, 10]. Thus, future versions of the model may add a fifth component—green workforce readiness-covering employee training, green competencies and participation in resource-saving initiatives. For the present model, however, the four resource-technological dimensions are retained to preserve a clear focus on production potential.

CONCLUSION

The study concludes that the green-economy adaptability of textile enterprises should be managed as an integral element of production potential rather than as a separate environmental function. Uzbekistan's policy targets for industrial energy efficiency, lower energy and greenhouse-gas intensity, renewable energy and resource saving create a measurable strategic context for enterprise-level green transformation [1, 6].

A Green Adaptability Index was proposed as $I_{green} = \sqrt[4]{(I_{energy} \times I_{water} \times I_{waste} \times I_{tech})}$. The model integrates energy efficiency, water efficiency, waste circularity and green-technology readiness. The geometric aggregation method makes the index sensitive to weak dimensions and therefore supports bottleneck-oriented management.

The practical implementation of the methodology requires enterprise data on electricity and fuel use, water withdrawal and reuse, textile waste generation and recycling, renewable-energy consumption, green investment and digital resource monitoring. Based on these data, managers can compare performance over time, identify the weakest component and direct investment to the area with the highest potential effect.

For textile enterprises, priority measures include energy audits and efficient equipment, renewable-energy generation, water metering and reuse, cleaner wet-processing technologies, cutting-waste optimization, recycling and circular material flows, as well as digital monitoring of resource consumption. These measures can simultaneously reduce environmental pressure, lower production costs and improve resilience to market and regulatory changes.

Further research should empirically validate the proposed index using multi-year data from textile enterprises, test alternative weighting methods and examine the relationship between I_green, production-capacity utilization, labour productivity, cost efficiency and export performance.

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