

IMPROVING ENVIRONMENTAL AUDIT MODELS IN BUSINESS ENTITIES

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Abstract. The study focuses on improving environmental audit models in business entities under the conditions of the green economy and digital transformation. The research highlights the need to move beyond the traditional compliance-checking function of environmental auditing toward risk-based, result-oriented, and data-driven approaches. The proposed model integrates technological tools such as ERP, MES, and LIMS systems with the ISO 14001 management cycle (Plan–Do–Check–Act) to create a unified and evidence-based audit framework.

The research methodology combines quantitative analysis, benchmarking, and the development of specific (intensity-based) indicators that link environmental performance with economic efficiency. A special contribution of the study is the Water-Scarcity-Adapted Environmental Compliance Index (WSA-ECI), designed to evaluate ecological performance in regions facing water stress. This index aggregates normalized and weighted indicators—such as water-use efficiency, reuse ratio, treatment effectiveness, and compliance rate—into a single measurable score, enabling comparative assessment across enterprises and regions.

The results demonstrate that the implementation of an improved environmental audit model enhances decision-making, increases resource efficiency, and strengthens environmental accountability. By integrating digital data flows, risk mapping, and real-time monitoring, the model transforms environmental auditing from a formal reporting procedure into a strategic management instrument. The study provides practical recommendations for policymakers, auditors, and industrial enterprises in Uzbekistan and other emerging economies to align environmental auditing with sustainable development goals and ESG standards.

Keywords: Environmental audit; Green economy; Risk-based auditing; Digital transformation; Water-Scarcity-Adapted Index; Sustainability reporting; ISO 14001; Resource efficiency; Uzbekistan; ESG integration.

Introduction

In the context of the green economy, the ecological dimension of business entities' activities is no longer limited to compliance discipline and permits but is becoming an integral factor of enterprise competitiveness, resource efficiency, and investment attractiveness. Therefore, updating the methodology for organizing and conducting environmental audits requires moving beyond the traditional “compliance verification” function toward a risk-oriented, results-oriented, and data-driven approach based on digital evidence.

Our research shows that enterprises tend to record environmental indicators mainly as final outcomes (such as emission or waste volumes). However, the causal chain linking these outcomes to their sources, technological processes, and management actions is not sufficiently revealed. Systematic use of specific (intensity) indicators, industry benchmarking, and the introduction of online monitoring mechanisms integrated with enterprise resource planning systems (ERP), manufacturing execution systems (MES), and laboratory information management systems (LIMS) remain insufficient. Moreover, uniformity in working papers,

materiality criteria, and the mathematical basis for sampling procedures often remain ambiguous. These shortcomings reduce the impact of environmental audits on management decision-making and weaken their connection with internal audits, environmental management systems under ISO 14001, enterprise resource planning systems, and Sustainability (GRI) reporting.

Literature Review

1. From compliance checking to risk-based, value-adding audit

Early environmental audits were designed chiefly as conformity checks against permits and procedural requirements, emphasizing documentation and episodic site inspections. This narrow remit has been criticized for weak managerial impact and limited predictive power (UNEP, 2022; OECD, 2023). The contemporary shift is toward risk-based, result-oriented models that locate environmental pressure at its sources (processes, inputs, technologies) and evaluate outcomes using specific (intensity) indicators and benchmarks. Empirical studies show that risk-prioritized scoping and materiality filtering improve detection of high-impact nonconformities and better align audit recommendations with operational decision cycles (World Bank, 2024; IFAC, 2023).

2. Standards and governance frameworks: ISO 14001, GRI, and assurance

ISO 14001 reframed environmental management around the PDCA cycle, requiring organizations to set measurable objectives, monitor performance, and institutionalize corrective action (ISO, 2015). The GRI Standards operationalize public transparency through standardized sustainability disclosures that can be directly fed by audit evidence trails (GRI, 2021). On the assurance side, IFAC and related guidance for extended external reporting emphasize criteria quality, evidence sufficiency, and materiality, supporting credible assurance over non-financial information and strengthening the role of internal controls over environmental data (IFAC, 2023; IASB/IFRS, 2023 for climate-related disclosures). Together, these frameworks create a governance scaffold within which environmental audit can move from periodic attestation to continuous performance improvement.

3. Digitalization and data pipelines (ERP–MES–LIMS)

Recent literature highlights the maturation of digital infrastructures—ERP for resource and cost flows, MES for shop-floor events, and LIMS for sampling and analytical chains—as a precondition for evidence-driven auditing (EEA, 2022). Integrating meters, sensors, and laboratory protocols into auditable data lakes enables near-real-time analytics (mass balance, anomaly detection, trend breaks). Studies report higher assurance quality when logs are traceable, version-controlled, and linked to calibration and chain-of-custody metadata, reducing measurement uncertainty and sample bias (World Bank, 2024; WRI, 2023).

4. Measuring performance: intensity metrics, benchmarking, and causality

The move from absolute totals to intensity metrics (e.g., water per unit output, energy per revenue) allows cross-entity and cross-regional comparability (OECD, 2023). Causal audits link emissions and waste to process parameters, maintenance regimes, and raw-material quality, enabling targeted interventions rather than generic compliance fixes. Benchmarking against sectoral quartiles and best-available techniques (BAT) helps set realistic target ranges (U and L bounds) for normalization and supports multi-year improvement trajectories.

5. Composite indices and water-scarcity-adapted evaluation

Composite indices aggregate normalized indicators into a single decision signal that managers and regulators can act on. In water-stressed contexts, the literature recommends combining use-efficiency, intake–discharge balance, treatment effectiveness, reuse ratio, network losses, groundwater recharge, and drought stress into a weighted score with transparent criteria (WRI, 2023; UNEP, 2022). The proposed Water-Scarcity-Adapted Environmental Compliance

Index (WSA-ECI) follows this line: (i) 0–1 normalization with directional logic (“higher/lower is better”), (ii) scientifically calibrated weights reflecting health, ecosystem, and economic risk channels, and (iii) explicit propagation of uncertainty bands into the composite score. Such indices are most effective when embedded in PDCA loops and tied to incentives (tariffs, tax relief, accelerated depreciation).

6. Regionalization: from plant-level audits to territorial governance

A growing stream of research advances regional environmental auditing—coordinating facility-level evidence within district or provincial risk maps. Evidence suggests that hotspot mapping (red/yellow/green zoning) focuses limited regulatory resources on high-risk corridors, while lighter analytic monitoring suffices elsewhere (UN ECE, 2022; World Bank, 2024). Regional dashboards and public disclosure improve social license and compliance through reputational pressure and citizen feedback loops.

7. Uzbekistan context: policy convergence and capacity challenges

Recent policy in Uzbekistan promotes a green-economy transition and formalizes environmental governance instruments, yet practical implementation still faces gaps in data quality, interoperability, sampling rigor, and consistent materiality thresholds (UNECE, 2022; national guidelines, 2023). Emerging academic work in the country underscores the need to integrate risk-based scoping, digital traceability, and economic valuation of audit recommendations to shift managerial attention from formal reporting to resource-efficiency gains and risk reduction.

8. Synthesis and research gaps

The literature converges on four pillars for next-generation environmental auditing in business entities:

Risk-based scoping and materiality anchored in causal analysis;

Digital evidence architectures (ERP–MES–LIMS, sensors, LIMS) ensuring traceability;

Comparability through normalized intensity metrics and composite indices;

Governance alignment via ISO 14001/GRI/assurance guidance and PDCA integration.

Gaps remain around (i) weight calibration in composite indices under heterogeneous climates and sectors, (ii) uncertainty communication in audit opinions, (iii) behavioral responses to incentives and disclosures, and (iv) scalable regional audit operating models linking facility data to territorial risk management. Addressing these gaps—especially in water-scarce regions—can convert environmental auditing from a periodic compliance ritual into a strategic engine of operational excellence and sustainable competitiveness.

Materials and Methods

Achieving ecological balance across all sectors of the economy involves the responsible management of limited natural resources, efficient energy use, and reducing production costs through the adoption of low-emission technologies. Transitioning to a green economy relies heavily on scientific advancements and innovations to promote societal stability and sustainable economic growth. The principles of the green economy are outlined through presidential decrees, policy decisions, and the insights of economists. This article was prepared using methods such as literature review, data analysis, and comparative studies.

Results and Discussion

In our view, in order to expand the application of environmental auditing in Uzbekistan, it is necessary to introduce **regional environmental auditing**. This procedure implies the replication and coordination of the model of the “Risk-Based, Result-Oriented, and Digitally Evidenced Environmental Audit (RBRD-EA)” developed at the enterprise level to the regional scale — that is, to integrate individual enterprise indicators and management cycles into a

unified information-analytical framework of district, city, or regional environmental governance. The main goal is to enable systematic monitoring of environmental risks at the territorial level, to strengthen regulatory mechanisms, and to enhance the efficiency of resource use.

The scientific foundation of this approach is based on several key principles: the cause–effect approach, materiality and intensity (specific) indicators, the formation of an open and verifiable evidence base, and the integration of the **ISO 14001 Plan–Do–Check–Act (PDCA)** cycle into regional management systems.

Stage 1. Establishing the Regulatory and Methodological Foundation

At the first stage, a regulatory-methodological foundation for environmental auditing within the regional framework is established. Here, national legislation and ministerial guidelines are harmonized with international approaches, terminology and indicator glossaries are clarified, and the regional audit objects — such as industrial clusters, transport corridors, urban infrastructure, municipal waste landfills, water bodies, and green areas — are categorized meaningfully.

At the same time, enterprise-level environmental passports, permits, laboratory protocols, and specific (intensity) indicators on emissions and waste are mapped into a unified regional indicator system. This mapping reduces interpretation discrepancies and ensures comparability across districts.

Stage 2. Organizing Reliable Data Flows

The second stage focuses on ensuring **reliable organization of regional data flows**. Streams from enterprise-level systems — such as enterprise resource planning (ERP), manufacturing execution systems (MES), laboratory information management systems (LIMS), and on-site sensors — are consolidated with regulatory data into a single regional database. This database guarantees traceability and reproducibility of evidence for verification.

Data cleansing, calibration, and synchronization algorithms are applied to ensure analytical quality. In cases of data gaps, targeted control measurements and focused inspections are conducted, with error margins transparently recorded and uncertainty intervals specified in the final conclusions.

Stage 3. Developing a Scientifically Grounded Regional Risk Map

The third stage is dedicated to constructing a **scientifically grounded environmental risk map**. The integrated risk-scoring concept is adapted to the regional scale, incorporating such factors as impact intensity, probability of occurrence, detectability, and compliance cost. These factors are weighted considering the industrial structure, demographic density, wind–hydrological conditions, and socially sensitive zones of the region.

As a result, “red,” “yellow,” and “green” zones are established and linked to specific sources and providers. The map helps to **prioritize audit resources** — conducting in-depth inspections in high-risk corridors and “hot spots,” while analytical monitoring is considered sufficient for low-risk zones.

Stage 4. Establishing a System of Regional Indicators

At the fourth stage, a **system of regional indicators** is formed. Indicators such as emission intensity, water and energy efficiency, waste recycling share, concentration of airborne particles, condition of water bodies, and noise and vibration levels are expressed in specific (intensity) formats and maintained alongside industry benchmarks.

These indicators are integrated into the **planning and accountability cycle** of regional management, with annual improvement intervals set and automatic alerts triggered when threshold deviations are detected.

Economic linkage of indicators is particularly important: the financial benefits of audit recommendations — such as resource savings, reduced fines, and decreased sanitary–epidemiological risks — are quantified, allowing assessment of the **return on environmental investments (REI)**.

Stage 5. Designing Sampling and Audit Procedures

The fifth stage defines the **sampling and testing design**. A stratified approach is used, considering regional variability and seasonal fluctuations: in high-risk strata, deep verification is conducted; in medium strata, combined procedures are used; and in low-risk strata, analytical reviews and trend monitoring suffice.

Sample sizes are calculated scientifically but can be recalibrated based on practical conditions; audit reports explicitly state sampling error boundaries.

Stage 6. Integrating Audit Findings into the PDCA Cycle

In the sixth stage, **audit findings are integrated into regional management mechanisms** through the PDCA cycle:

- **Plan:** Set goals and indicators based on the risk map;
- **Do:** Implement resource reallocation, technological modernization, and environmental investment (filters, treatment plants, etc.);
- **Check:** Evaluate achievements in indicators and compliance metrics;
- **Act:** Introduce corrective and incentive mechanisms.

Thus, the audit conclusion evolves from a “one-time report” into a mechanism for **continuous improvement of governance**.

Stage 7. Public Communication and Monitoring

The seventh stage emphasizes monitoring and stakeholder communication. **Key indicators are published in open formats via a regional information dashboard, and an interactive channel for public complaints and suggestions is established. Transparency, independent evaluation, and external verification mechanisms are promoted, thereby strengthening social trust and accelerating the implementation of audit recommendations.**

Partnerships with universities and research institutions facilitate the establishment of regional laboratory networks and professional training programs, ensuring continuous capacity building.

Stage 8. Financing and Economic Incentives

The eighth stage addresses **financing and incentive mechanisms**. Blended financing schemes — combining enterprise funds, local budgets, international grants, and credit lines — are applied for regional environmental projects.

Incentives include tax benefits, “green tariffs,” or accelerated depreciation for enterprises achieving significant improvements in indicators. Conversely, non-compliance in high-risk zones triggers a gradual tightening of administrative measures.

Stage 9. Evaluation and Recalibration

The ninth stage involves **evaluation and recalibration**. Starting from the first year of implementation, annual analyses of results are conducted; baseline indicator values are updated; risk maps are reassessed; and the audit program is adjusted accordingly.

Materiality thresholds, specific indicator formulas, or verification procedures are refined to reflect evolving regional conditions.

It is noteworthy that this scientific framework for implementing regional environmental auditing systematically integrates methods and indicators developed at the enterprise level into a regional context. It enables **evidence-based decision-making**, provides real-time alerts, and transparently demonstrates the economic benefits of environmental measures.

As a result, emission and waste intensities steadily decrease, water and energy efficiency improve, permit violations decline sharply, and compliance with audit recommendations rises significantly. This approach is directly linked to the objectives stated in the introduction — establishing an applied and scientific foundation for embedding environmental audit into regional management as a modern, risk- and result-oriented, digitally supported tool.

Unlike traditional corporate environmental audits, this innovation focuses on conducting audits **across entire territories** (regions, districts). The ecological, economic, and social conditions of the region are comprehensively assessed, environmental risks are identified, and recommendations for mitigation are developed — all contributing to **regional sustainable development**.

Alongside the introduction of regional environmental auditing, a proposal has been developed to implement a **Water-Scarcity-Adapted Environmental Compliance Index (WSA-ECI)**.

Firstly, as demand for water in industrial, agricultural, and domestic sectors continues to grow, the volume of available resources remains unstable and varies under climate influences. In such conditions, simple “compliance checks” based solely on permits and reports cannot adequately support management decisions, as they fail to measure the combined effects of water-use intensity, effluent stability, reuse rate, and drought adaptation.

Secondly, regional management involves multiple interacting sources — enterprises, utilities, irrigated areas, and natural reservoirs — complicating the cause-effect chain. Therefore, aggregating a set of digital, result-oriented, and risk-prioritized indicators into a **single index** simplifies management and clarifies accountability.

The proposed index functions as a “multi-factor thermometer” for assessing adaptation to water scarcity. It integrates indicators such as water-use efficiency, intake-discharge balance, wastewater treatment performance, reuse ratio, water losses, reservoir and groundwater recharge rates, and physical-geographical risks (drought, salinization).

All indicators are expressed in **specific (intensity)** form — e.g., water consumption per unit of output or income, per-capita access to clean water, or the ratio of pollutant concentration in wastewater to the normative limit — allowing **comparative analysis** across regions and sectors regardless of size or population.

The index is constructed step by step:

1. A reliable data infrastructure is formed by integrating on-site meters and sensors, laboratory protocols, ERP systems, utility registries, and regulatory data into a unified regional repository, with quality control, calibration, and gap-filling mechanisms.

2. Indicators are normalized within the 0–1 range: 0 represents minimal compliance (poor state), and 1 represents full compliance (good state), with benchmark ranges adjusted for sectoral and climatic specifics.

3. Normalized indicators are aggregated using a **weighted average**, where weights are calibrated scientifically according to real channels of water-scarcity impact — such as drinking-water security, ecosystem resilience, potential economic loss, and public-health criteria.

The resulting composite score (from 0 to 1) represents each district's or city's **territorial compliance level**, which is visualized on maps using green–yellow–red zoning.

The managerial advantage of this index lies in its **direct linkage with the PDCA cycle**.

- In the Plan phase, annual improvement targets for each indicator are set.
- In the Do phase, measures such as technological modernization, water-saving equipment, wastewater-treatment upgrades, and loss-reduction initiatives are implemented.
- In the Check phase, the index trend, seasonal variations, and inter-regional differences are analyzed.
- In the Act phase, targeted programs are launched for “red zones” with low scores, while high-performing areas receive incentives.

Through a **value-chain perspective**, every action is economically quantified — accounting for water savings, risk and penalty reductions, improved drinking-water quality, disease prevention, and minimized production disruptions — linking environmental actions to investment decisions.

The index enhances **decision-making transparency**: authorities, enterprises, and the public communicate in a “common measurement language,” easily identifying weak indicators that lower the overall score, pinpointing problem sources, and assigning responsibility.

Its open methodology enables **external verification** — independent assessors or academic institutions can review results and propose improvements. Thus, the index becomes not merely a rating tool but a **driver of continuous improvement**.

Naturally, certain **limitations** remain — including data continuity and quality, synchronization among diverse sources, and short-term impacts of seasonal or emergency factors. Therefore, normalization ranges and weights are revised annually to reflect climate-change trends, new technologies, and sanitary standards.

If necessary, benchmark values are differentiated by climate zones to ensure **comparative fairness**.

In summary, the introduction of a **Water-Scarcity-Adapted Environmental Compliance Index** strengthens the practical implementation of the risk- and result-oriented, digitally evidenced approach outlined earlier. The index unifies management into a single information framework, defines clear priorities for improving resource efficiency, and links investment and policy measures to economic effectiveness.

Most importantly, it transforms audit findings from “reports” into “decisions” — through transparent criteria, real-time alerts, and continuous feedback mechanisms — thereby

contributing to the **enhancement of regional water security**. Table 1 below presents the main indicators and formulas of the Water-Scarcity-Adapted Environmental Compliance Index.

Table 1.

Water-Scarcity-Adapted Environmental Audit Compliance Index — Formulary

1. Key indicators and their formulas (region h , period t)

Indicator name	Symbol	Formula (Word Eq.)	Explanation
Water-use efficiency (by revenue)	WUE	$WUE_{(h,t)} = (\text{Water consumption}_{(h,t)} \text{ (m}^3\text{)}) / (\text{Revenue}_{(h,t)} \text{ (million UZS)})$	Lower is better
Net water-balance load	NWB	$NWB_{(h,t)} = (\text{Water intake}_{(h,t)} - \text{Water return}_{(h,t)}) / (\text{Annual recharge}_{(h)})$	Lower is better
Wastewater-treatment efficiency	WTE	$WTE_{(h,t)} = 1 - (\text{Pollution load(out)}_{(h,t)}) / (\text{Pollution load(in)}_{(h,t)})$	Range 0–1; higher is better
Reuse ratio	RR	$RR_{(h,t)} = (\text{Reused water}_{(h,t)}) / (\text{Collected wastewater}_{(h,t)})$	Range 0–1; higher is better
Loss share (utility networks)	LS	$LS_{(h,t)} = (\text{Network inflow}_{(h,t)} - \text{Metered consumption}_{(h,t)}) / (\text{Network inflow}_{(h,t)})$	Lower is better
Groundwater-recharge ratio	GRR	$GRR_{(h,t)} = (\text{Groundwater recharge}_{(h)}) / (\text{Groundwater abstraction}_{(h,t)})$	Values ≥ 1 are desirable
Drought-impact coefficient	DIC	$DIC_{(h,t)} = \psi(\text{SPEI}_{(h,t)}) \in [0,1]$	Climatic indicator; 1 = favorable
Supply-stability ratio (population)	SSR	$SSR_{(h,t)} = (\text{Clean drinking water (m}^3\text{/capita)}_{(h,t)}) / (\text{Minimum norm (m}^3\text{/capita)})$	Values ≥ 1 are good
Legal-compliance level	LCL	$LCL_{(h,t)} = 1 - (\text{Serious violations}_{(h,t)}) / \max(1, \text{Audited entities}_{(h,t)})$	Range 0–1; higher is better

2. Normalization (0–1 Range)

2.1. Goal-Oriented Normalization (0–1)

For each indicator X , the direction of improvement — whether “lower is better” or “higher is better” — is first determined. The target (ideal) value U_X and the minimum acceptable threshold L_X are defined according to the climatic zone and sectoral characteristics of the region.

For “**lower is better**” type indicators (e.g., WUE, NWB, LS), the normalization formula is:

$$S_x = \text{clamp} \left(\frac{U_x - X}{U_x - L_x}, 0, 1 \right)$$

For “**higher is better**” type indicators (e.g., WTE, RR, GRR, SSR, LCL), the normalization formula is as follows:

$$S_x = \text{clamp} \left(\frac{X - L_x}{U_x - L_x}, 0, 1 \right)$$

If the **drought indicator** (DICD) is **pre-mapped to the 0–1 range**, additional normalization is not required. In this case, the value obtained from the climatic index (e.g., Standardized Precipitation–Evapotranspiration Index, SPEI) is directly used in its normalized for:

$$S_{QT} = QT$$

The core idea behind the proposed index is that **positive outcomes** (such as water treatment, reuse, supply stability, and groundwater recharge) increase the score, while **pressures** (such as water scarcity, pollution, or drought intensity) decrease it. Meanwhile, **compliance** (e.g., absence of permit violations) acts as a multiplicative coefficient that adjusts the final composite score proportionally to regulatory performance.

Table 2.

Roadmap for Implementing Environmental Audit and Expected Quick Wins

Phase	Main Activities	Expected Quick Results
0–3 months	Diagnostics, indicator passporting, risk mapping, and templates	Identification of losses, immediate corrective actions
4–9 months	Data pipeline setup, dashboard creation, 2–3 pilot audits	Reduction of water losses by 5–10%
10–18 months	Corporate-scale expansion, incentive and monitoring mechanisms, external evaluation	Significant increase in water reuse

Explanation of Phases

0–3 months (Diagnostics, Indicator Passports, Risk Map, Templates): During this stage, a rapid “X-ray” of internal processes and facilities is performed. “Passports” for specific (intensity) indicators are developed — specifying data source, measurement frequency, responsible unit, and target range — while audit templates are standardized. Expected quick wins include immediate savings achieved by correcting visible technical faults and procedural violations, calibrating meters, and reducing leakages or unnecessary washing operations.

4–9 months (Data Pipeline, Dashboard, 2–3 Pilot Audits): Data from production, laboratory, and metering systems are cleaned, standardized, and integrated into a central repository, then visualized through a near-real-time analytical dashboard. Pilot

audits are conducted to test sampling, mass balance, and compliance-check procedures; process maps are refined accordingly. By the end of this phase, network water losses are expected to drop by **5–10%**, treatment regimes become optimized, and the frequency of emergency discharges decreases.

10–18 months (Corporate Expansion, Incentives/Monitoring, External Evaluation): Proven solutions are scaled across the enterprise. Employee incentive systems and continuous monitoring mechanisms are implemented. External verification by auditors or laboratories validates the results. Key outcomes include a **notable increase in water reuse ratio**, a **sharp decline in permit violations**, and a **steady upward trend in the Environmental Sustainability Index (ESI)** or internal compliance score.

At the end of each phase, a **minimal indicator set** should be documented:

- Water losses (%)
- Wastewater-treatment efficiency (0–1)
- Reuse ratio (%)
- Number of serious violations (cases)
- Overall compliance index (0–100)

This approach directly links the roadmap to measurable operational outcomes and provides a clear analytical foundation for subsequent management decisions.

Conclusion

In the context of the transition toward a green economy and sustainable management practices, improving environmental audit models in business entities is not merely a regulatory requirement but a strategic necessity. The traditional compliance-oriented audit, which primarily focused on verifying adherence to environmental standards, is gradually being replaced by **risk-based, result-oriented, and data-driven approaches** that enhance the decision-making capacity of enterprises and regulators alike.

The research demonstrates that the effectiveness of environmental auditing depends on its ability to integrate **technological, managerial, and analytical dimensions**. The adoption of digital tools — such as Enterprise Resource Planning (ERP), Manufacturing Execution Systems (MES), and Laboratory Information Management Systems (LIMS) — allows real-time data collection and monitoring, transforming the audit from a periodic control activity into a **continuous improvement process**.

Improved environmental audit models emphasize the **cause–effect linkage** between emissions, resource use, and management responses. They utilize **specific (intensity-based) indicators**, benchmarking, and regional risk mapping to identify not only the outcomes but also the underlying drivers of environmental impact. This analytical depth enables enterprises to detect inefficiencies, optimize resource use, and strengthen environmental responsibility across production cycles.

Furthermore, incorporating **quantitative evaluation tools**—such as the Water-Scarcity-Adapted Environmental Compliance Index (WSA-ECI)—ensures comparability across regions and sectors, allowing the assessment of environmental performance in measurable, transparent, and economically interpretable terms. Linking audit findings with financial and sustainability metrics enhances both accountability and the attractiveness of enterprises to investors committed to ESG (Environmental, Social, and Governance) principles.

The proposed framework thus redefines environmental auditing as a **dynamic management instrument**, integrating planning, execution, verification, and corrective action (the PDCA cycle). This ensures that audit results contribute not only to compliance verification

but also to **strategic value creation**, enabling organizations to reduce environmental risks, improve operational efficiency, and reinforce their reputation in competitive markets.

In conclusion, modernized environmental audit models for business entities should be grounded in:

1. **Scientific and quantitative methodologies** that align ecological and economic efficiency;
2. **Integration of digital evidence systems** for transparent, traceable data management;
3. **Risk-oriented and adaptive frameworks** tailored to sectoral and regional conditions; and
4. **Continuous feedback mechanisms** that link audit outcomes to performance incentives and sustainable development goals.

Such an approach transforms environmental auditing into a key driver of sustainable competitiveness, ensuring that ecological responsibility and economic growth advance in harmony.

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