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INTEGRATING INDUSTRY 5.0 TECHNOLOGIES INTO ENTERPRISE SYSTEMS: A SUSTAINABILITY APPROACH FOR NESTE

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Abstract. This case study explores the integration of Industry 5.0 technologies — Artificial Intelligence (AI), Internet of Things (IoT), and Blockchain—into the enterprise systems of Neste, a global leader in renewable fuels and circular economy solutions. The study examines how these technologies can enhance operational sustainability and support Environmental, Social, and Governance (ESG) goals by addressing specific gaps in the company's digital infrastructure. Through a layered enterprise architecture analysis, the paper identifies opportunities for improving predictive capabilities, real-time monitoring, and ESG transparency. A three-phase roadmap is proposed to guide Neste's transition toward a more human-centric and sustainable digital operating model. The study contributes to the literature by offering a practical, standards-aligned framework that supports long-term value creation and ESG compliance through technological innovation.

Keywords: industry 5.0, sustainability, environmental social governance, artificial intelligence, internet of things, blockchain, enterprise architecture, digital transformation

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ИНТЕГРАЦИЯ ТЕХНОЛОГИЙ ИНДУСТРИИ 5.0 В КОРПОРАТИВНЫЕ СИСТЕМЫ: ПОДХОД К УСТОЙЧИВОМУ РАЗВИТИЮ ДЛЯ КОМПАНИИ NESTE

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Аннотация. В данном исследовании рассматривается интеграция технологий Индустрии 5.0 — искусственного интеллекта (ИИ), Интернета вещей (IoT) и блокчейна — в корпоративные системы компании Neste, мирового лидера в области возобновляемых видов топлива и решений для экономики замкнутого цикла. Исследование анализирует, как эти технологии могут повысить операционную устойчивость и поддержать цели в области экологии, социальной ответственности и корпоративного управления (ESG) путем устранения конкретных пробелов в цифровой инфраструктуре компании. С помощью многоуровневого анализа корпоративной архитектуры в работе определены возможности для улучшения прогнозных возможностей, мониторинга в реальном времени и прозрачности в вопросах ESG. Предлагается трехэтапная дорожная карта для перехода Neste к более человекоцентричной и устойчивой цифровой операционной модели. Исследование вносит вклад в литературу, предлагая практическую, соответствующую стандартам структуру, которая поддерживает создание долгосрочной ценности и соблюдение требований ESG посредством технологических инноваций.

Ключевые слова: индустрия 5.0, устойчивое развитие, экологическое социальное управление, искусственный интеллект, интернет вещей, блокчейн, корпоративная архитектура, цифровая трансформация

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Introduction

The transition from Industry 4.0 to Industry 5.0 marks a significant evolution in how digital technologies are applied within enterprises. While Industry 4.0 emphasized automation, interconnectivity, and operational efficiency, Industry 5.0 promotes a human-centric, sustainable, and resilient approach to value creation. This paradigm shift is particularly relevant as firms face increasing pressure from regulators, investors, and society to meet environmental, social, and governance (ESG) goals while maintaining competitiveness.

In parallel, enterprise systems—such as Enterprise Asset Management (EAM), Supply Chain Management (SCM), and Enterprise Resource Planning (ERP)—are becoming critical platforms for embedding sustainability objectives. However, many of these systems remain fragmented, reactive, and limited in their ability to support real-time ESG performance monitoring or compliance with circular economy principles.

Neste, a Finland-based global leader in renewable fuels and circular solutions, offers a relevant context to explore how emerging technologies associated with Industry 5.0—namely Artificial Intelligence (AI), the Internet of Things (IoT), and Blockchain—can be strategically integrated into enterprise systems to enhance sustainability outcomes. Despite the company's commitment to carbon-neutral production by 2035, it continues to face challenges in predictive maintenance, real-time emissions monitoring, and traceability in ESG reporting.

This study addresses the following research question:

How can AI, IoT, and Blockchain be integrated into enterprise systems to improve ESG performance and sustainability outcomes in industrial organizations?

To investigate this, we adopt a qualitative case study approach grounded in enterprise architecture analysis. Through the case of Neste, the study identifies key technological and functional gaps, maps relevant technologies to ESG objectives, and develops a layered integration framework supported by a phased implementation roadmap.

The study contributes to the information systems field by offering a replicable digital transformation model that aligns with Industry 5.0 principles and ESG frameworks.

It should be noted that the proposed framework is conceptual and derived from publicly available data and secondary sources. While this approach enables a structured analysis, it does not capture all operational constraints faced during real-world implementation. Therefore, the quantitative impacts discussed should be interpreted as indicative rather than deterministic.

Materials and Methods

This research adopts a qualitative case study methodology to explore the integration of Industry 5.0 technologies into enterprise systems for enhancing sustainability performance. The case study approach is appropriate for examining contemporary phenomena within real-world contexts, especially when boundaries between the phenomenon and context are not clearly defined (Yin, 2018). By focusing on a single, information-rich case, the study aims to generate deep, contextualized insights into how Artificial Intelligence (AI), the Internet of Things (IoT), and Blockchain can be embedded within enterprise architecture to support Environmental, Social, and Governance (ESG) goals.

Case Selection

Neste was selected as the focal case due to its recognized leadership in renewable fuels and circular economy innovation. As a company that has publicly committed to achieving carbon-neutral production by 2035 and reducing customer greenhouse gas emissions by 20 million tons annually by 2030, Neste presents a compelling setting for studying the alignment of sustainability strategy with digital transformation initiatives (Neste, 2023). Its complex industrial operations and advanced digital infrastructure also provide a suitable testbed for investigating how Industry 5.0 technologies can be operationalized.

Data Sources

The analysis draws upon multiple secondary data sources to ensure triangulation and enhance validity. These include:

— Publicly available corporate sustainability and digital transformation reports (e.g., Neste's Annual Sustainability Reports)

— Industry white papers and digital benchmarks

— International standards such as ISO 9001 (Quality Management Systems), ISO 14001 (Environmental Management Systems), and ISO 50001 (Energy Management Systems)

— ESG disclosure frameworks including the Global Reporting Initiative (GRI), Sustainability Accounting Standards Board (SASB), and Task Force on Climate-related Financial Disclosures (TCFD) (GRI, 2021; SASB, 2020)

— Academic and practitioner literature on AI, IoT, and Blockchain integration in enterprise systems (e.g., Muller et al., 2021; Wang et al., 2020)

Analytical Framework

The research follows a three-step analytical framework aligned with enterprise architecture modeling principles (TOGAF, 2018), consisting of:

1. Enterprise Systems Assessment

Evaluation of Neste's existing enterprise systems—Enterprise Asset Management (EAM), Supply Chain Management (SCM), and Enterprise Resource Planning (ERP)—to identify architectural and functional gaps hindering ESG performance.

2. Technology-to-ESG Mapping

Mapping the capabilities of AI, IoT, and Blockchain technologies to specific sustainability indicators and process deficiencies. This includes identifying how these technologies contribute to improving resource efficiency, emissions tracking, and transparency.

3. Framework and Roadmap Development

Designing a multi-layered integration framework (business, application, and technology layers) and a phased roadmap to support scalable, standards-aligned digital transformation aligned with ESG targets.

Results and Discussion

Enterprise System Assessment and Integration Opportunities

Enterprise Asset Management (EAM): Neste's EAM schedules and logs maintenance but remains largely time- or usage-based. It does not use sensor-driven analytics to predict failures or optimize energy use. We identified key gaps: no predictive analytics, no real-time monitoring of heavy machinery, and limited emissions optimization during maintenance. These issues mirror broader industry patterns: without AI-driven insights, maintenance tends to be reactive, causing unplanned downtime and waste. For example, case studies show that AI-based predictive maintenance on sensor data can forecast equipment health and cut downtime significantly (Marti-Puig et al., 2024; Ignatiev and Levina, 2024). IoT sensors (vibration, temperature, etc.) can continuously feed health and energy data, enabling condition-based scheduling in line with ISO 50001 principles. In practice, linking sensors to an AI engine has been shown to detect faults early and eliminate some outages (Uhlmann, Polte & Geisert, 2024). This transition from "run-to-failure" to condition-based maintenance can reduce resource waste and energy use.

Supply Chain Management (SCM): Neste's SCM handles procurement, inventory and logistics, but only tracks materials in batches after the fact. It lacks live visibility of shipments, and sustainability credentials are checked manually. We found no IoT tracking of renewable feedstocks, weak ESG data from suppliers, and slow audit processes for certifications. Industry solutions exist: GPS trackers and environmental sensors on containers can stream location and condition data in real time, greatly improving logistics efficiency. Studies on blockchain in IIoT context show that combining IoT and blockchain creates an immutable, real-time ledger of supply flows (Soori et al., 2024). For example, IoT sensors can monitor transport conditions, while blockchain records each supply chain event securely. This combination enables end-to-end traceability of raw materials and fuels. AI also enhances SCM: by analyzing traffic and weather data, AI can optimize routing to cut fuel consumption (a model shown to reduce transport energy use by ~10%). Blockchain's immutable chain then verifies that feedstocks are sustainably sourced, automating audits and building trust (Shen ,Cui ,Chen ,Huang & Sarker S, 2025). Enterprise Resource Planning (ERP): Neste's ERP integrates finance and some ops with nascent sustainability reporting. However, sustainability data largely lives in silos – one team's spreadsheets are another's. Real-time dashboards for emissions or resource use are absent, and reporting is manual with low auditability. This impairs transparency and response time. AI analytics can remedy this by unifying data streams (from IoT sensors, maintenance logs, supply records) to automatically flag ESG KPIs out of range (Ayvaz & Alpay, 2021). For example, an AI engine could detect a spike in energy use or a deviation in GHG intensity and alert managers instantly. Blockchain adds integrity: by recording emissions data and carbon credit transactions in a tamper-proof ledger, it prevents post-hoc manipulation. Prior work in industrial informatics suggests blockchain can secure ESG disclosures: sensor data feeding directly into blockchain eliminates "garbage in, garbage out" errors and ensures traceable audit trails (Shen et al.,2025; Martini, Bellisario, & Coletti, 2024).

Integration Framework and Roadmap

To implement these solutions, we propose a layered integration framework (aligned with TOGAF). The Business layer embeds ESG and circular economy goals into corporate strategy. Sustainability KPIs (e.g., ISO 14001, ISO 50001 targets) are linked to digital initiatives so that technology projects explicitly support those goals. The Application layer integrates AI modules into EAM and SCM and advanced analytics into ERP. For instance, an AI analytics service can push maintenance forecasts into EAM, supply-demand forecasts into SCM, and ESG alerts into ERP. The Technology layer deploys IoT networks and blockchain infrastructure: IoT devices across plants and logistics capture live data, while blockchain nodes store traceability and audit records. This architecture ensures seamless, ESG-aligned data flows. AI engines consume sensor data to drive EAM and SCM decisions (Marti-Puig et al., 2024). IoT feeds live production and transport data into SCM/EAM and into a unified data lake for ERP analysis. Blockchain interfaces with ERP/SCM to register transactions and trigger smart contracts for compliance checks (Shen et al., 2025).

Implementation Roadmap:

We outline a phased deployment. In Phase 1 (0–6 months), pilot programs validate core use cases with minimal disruption. For example, trials might deploy AI predictive maintenance on one plant's critical assets, install IoT sensors on key emissions sources, and set up a blockchain proof-of-concept for one supply chain stream. These pilots generate initial ROI and technical lessons. In Phase 2 (6–18 months), successful pilots are scaled: AI tools expand into SCM demand forecasting and emissions modeling; IoT sensors cover all major equipment and vehicles; blockchain is rolled into the ERP for carbon accounting and sustainability reports. By Phase 2 end, ESG dashboards become live across core operations. Phase 3 (18–36 months) focuses on optimization and expansion: aggregated AI/IoT insights automate workflows and energy balancing; smart contracts fully automate compliance and audits; the system is extended to new business units and global sites. Throughout, progress is tracked by milestones: e.g., initial pilots achieve $\geq$10% downtime reduction, Phase 2 reaches ~70% system coverage, and Phase 3 realizes $\geq$50% faster ESG reporting.

Table 1. Integration of Industry 5.0 Technologies and ESG Improvements.

System	Identified Gap	Technology Applied	ESG Improvement	Impact
EAM (Enterprise Asset Management)	Reactive, time-based maintenance; energy inefficiency	AI + IoT (predictive maintenance, real-time monitoring)	Reduced resource waste and energy use	~20% reduction in downtime; ~15% less maintenance energy use
SCM (Supply Chain Management)	Lack of real-time visibility; inefficient routing; fragmented supplier data	IoT + AI (live tracking, predictive logistics); Blockchain (traceability ledger)	Optimized transport; verified sustainable sourcing	~10% drop in transport fuel; 100% traceability; 50% faster audits
ERP (Enterprise Resource Planning)	Siloed ESG data; manual reporting; risk of tampering	AI (ESG analytics); Blockchain (secure recordkeeping)	Transparent ESG dashboards; tamper-proof compliance	Reporting time cut by 50%; 0 discrepancies in audits

Impact Analysis: discrepancies in audits The proposed integration is expected to significantly boost ESG performance along three dimensions.

Resource Efficiency: AI-driven predictive maintenance and IoT monitoring directly improve resource use. By moving from scheduled to condition-based maintenance, machines run more reliably. The literature indicates such AI systems can substantially reduce downtime and energy waste (Marti-Puig et al., 2024). IoT sensors continuously measure energy and material flows at the factory, making inefficiencies immediately visible. For instance, live energy dashboards enable teams to spot and fix leaks or machine idling. Blockchain contributes by streamlining verification of sustainable practices (e.g., renewable materials usage) and reducing audit labor. KPIs reflect these gains: unplanned downtime can fall by ~20%, and maintenance energy use by ~15% (Marti-Puig et al., 2024)., meaning more production for the same inputs.

Emissions Reduction: AI models can predict emissions from various production scenarios. By simulating process changes or startup sequences, the system suggests low-carbon operating modes proactively. Real-time IoT sensors (e.g., CO_2 or NOx detectors on chimneys) then alert operators to anomalies. Quick interventions reduce spikes and overall emissions. A blockchain ledger ensures all emissions data are recorded immutably, simplifying regulatory audits. Blockchain-based carbon credit platforms, as Soori et al report, can cut audit time and costs (Soori et al., 2024). This combined approach can yield substantial CO_2 cuts; for example, pilot zones may see 10–30% lower emissions under AI/IoT control. Response cycles also shorten, as issues are detected in near real time.

Transparency in ESG Reporting: By funneling sensor and operational data into ERP, AI-enabled platforms can generate ESG reports automatically. This reduces manual entry errors and slashes reporting time. We anticipate up to a 50% reduction in report preparation based on analogous automation projects. Blockchain seals the trust: immutable ledgers and smart contracts guarantee that once data (e.g., energy usage, carbon output) is logged, it cannot be altered. This fortifies compliance with GRI/SASB frameworks. In the supply chain, blockchain ensures end-to-end traceability of renewable inputs: every batch's origin is recorded. The result is 100% provenance of critical materials, enhancing stakeholder trust. Documented blockchain pilots in consumer goods supply chains, including Unilever's traceability initiatives, suggest that blockchain-based systems can enhance the credibility of sustainability claims by strengthening data provenance and auditability (Shen et al., 2025). In a similar manner, the combined integration of AI, IoT, and blockchain within enterprise systems has the potential to support more transparent and data-driven ESG governance at Neste. By improving the monitoring of resource use and greenhouse gas emissions, such an approach is expected to contribute to the company's carbon-neutral production objectives. More reliable and timely disclosures may also strengthen stakeholder confidence by reducing information asymmetry and post hoc data manipulation.

Strategic Integration and Change Management

Effective implementation requires a coherent integration strategy. We advocate a modular, API-driven architecture so that innew AI/IoT components plug into existing EAM/SCM/ERP systems. For example, AI analytic services process maintenance history and sensor streams to output maintenance schedules into EAM (Marti-Puig et al., 2024). IoT data feeds seamlessly into SCM for inventory tracking and into EAM for machine health. Blockchain nodes are connected to ERP/SCM to store transactions and to smart contracts that automate supplier ESG verifications (Shen et al., 2025). Edge computing handles time-critical sensor data on-site, while cloud/central servers perform batch analytics. Smart contracts automatically check supplier certificates, emissions thresholds, or carbon credit rules without manual intervention.

Change Management: Technology is only half the story. Staff must be trained on these new systems — from interpreting IoT dashboards to understanding AI-generated maintenance alerts and blockchain records. Stakeholders (sustainability officers, IT, operations) should guide the process from the start to align digital goals with business needs. We recommend an iterative rollout: begin with pilots to demonstrate value, gather feedback, then expand. Communication is key to overcome resistance: show how these tools reduce drudgery (less manual reporting) and improve outcomes.

Risk Mitigation: Key risks include resistance to change, integration complexity, and cybersecurity. We mitigate these by using modular design and middleware for interoperability, setting up a cross-functional steering committee for approach itself allows early identification and correction of issues.

Conclusion

This case study shows that AI, IoT, and blockchain can be woven into enterprise systems to drive sustainability. By transforming EAM, SCM, and ERP from siloed tools into a predictive, transparent platform, Neste can meet its ESG goals more effectively. Specifically, we found that embedding AI enables proactive maintenance and emissions management; IoT provides the real-time data backbone for efficiency; and blockchain guarantees data integrity and traceability of ESG information (Khan et al., 2025; Rame, Purwanto & Sudarno, 2024). The proposed integration framework and roadmap answer our research question: they illustrate how these technologies work together to improve ESG performance, with clear examples (e.g., reduced downtime, fuel savings, audit acceleration).

Managers can use this model as practical guidance: start small with pilots, align each tech deployment with specific sustainability KPIs, and expand as gains are realized. For researchers, the study offers a structured link between Industry 5.0 concepts and enterprise architecture, suggesting many future questions (e.g., cross-industry validation, economic impact analysis). As Industry 5.0 grows, our findings imply that success lies in blending technology with human-centric sustainability governance.

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