MINISTERUL EDUCAȚIEI NAȚIONALE
ROMÂNIA
UNIVERSITATEA DE MEDICINĂ, FARMACIE, ȘTIINȚE ȘI TEHNOLOGIE „GEORGE EMIL PALADE" DIN TÂRGU MUREȘ

Acta Marisiensis. Seria Technologica
Vol. 21 (XXXVIII) no. 2, 2024
ISSN 2668-4217, ISSN-L 2668-4217

ROLE OF ARTIFICIAL INTELLIGENCE IN ENHANCING SUSTAINABILITY REPORTING AND GREEN ACCOUNTING IN INDUSTRY 4.0

Ayesha TARIQ[1], Mohd Reyaz Ur RAHIM[2]
[1,2]*Integral University, Lucknow, India*

[1]ayeshatq@student.iul.ac.in ,[2] rrahim@iul.ac.in

Abstract

This study explores the role of artificial intelligence (AI) in enhancing sustainability reporting and green accounting within the context of Industry 4.0. By drawing on sustainability accounting theory and integrating emerging technologies, the research addresses the limitations of traditional sustainability reporting, such as inefficiencies in data collection, lack of real-time feedback, and resource constraints. AI, with its ability to automate processes, streamline data analysis, and provide continuous monitoring, offers a promising solution to these challenges. The research employs qualitative case studies to demonstrate how AI-driven methods improve the accuracy and productivity of sustainability reporting. Findings indicate that AI facilitates more effective resource utilization, provides real-time insights, and enhances data-driven decision-making, which collectively contribute to more sustainable business practices. The paper concludes that AI's integration into sustainability accounting not only improves transparency and accountability but also accelerates the transition towards environmentally conscious business operations in the digital age of Industry 4.0.

Key words: Industry 4.0, artificial intelligence, sustainability reporting, green accounting, corporate governance

1. Introduction

Industry 4.0 represents the current phase of industrial evolution, distinguished by the integration of advanced technologies such as artificial intelligence (AI), the Internet of Things (IoT), and big data analytics into the industrial and manufacturing sectors. This technological convergence facilitates the development of interconnected cyber-physical systems, which enable more intelligent, autonomous production processes. The transformation of conventional manufacturing into "smart factories" is a core feature of Industry 4.0, wherein machines communicate with each other to optimize workflows in real-time, minimizing human intervention. These innovations significantly enhance production efficiency, reduce operational downtime, and increase precision, contributing to a paradigm shift toward highly automated, data-driven industrial environments [1].

However, this rapid technological advancement introduces new challenges, particularly concerning environmental sustainability. The expansion of smart manufacturing processes raises concerns regarding increased energy consumption, greenhouse gas emissions, and the depletion of natural resources.

As production scales up, these sustainability issues become more pronounced, requiring robust strategies to mitigate the environmental impacts associated with Industry 4.0 technologies. Addressing these challenges is critical to ensuring that the benefits of industrial automation and efficiency gains do not come at the expense of long-term ecological sustainability.

1.1 Sustainability Reporting and Green Accounting

Sustainability reporting refers to the assessment and disclosure of a company's performance in relation to environmental, social, and governance (ESG) factors.

This reporting framework enables various stakeholders—including investors, customers, and regulatory bodies to evaluate the broader environmental and social impacts of a company's operations. It provides transparency regarding a company's commitment to sustainability and its adherence to corporate social responsibility (CSR) principles.

On the other hand, green accounting, also known as environmental accounting, is a specialized field within accounting that integrates environmental costs into traditional financial accounting practices.

Unlike conventional accounting, which focuses solely on financial transactions, green accounting takes into account factors such as resource consumption, waste generation, and environmental degradation. This approach allows companies to present a more comprehensive view of their financial position by accounting for ecological externalities, including both the direct and indirect environmental costs associated with their operations [2].

As global attention increasingly centers on corporate responsibility and the achievement of sustainable development goals (SDGs), both sustainability reporting and green accounting have become essential tools for businesses seeking to align their practices with broader environmental objectives [3]. These frameworks not only support regulatory compliance but also enhance a company's reputation and competitiveness in markets that prioritize sustainability.

1.2 AI's Contribution

Artificial intelligence (AI) plays an increasingly vital role in addressing the complexities of sustainability reporting and green accounting, particularly within the Industry 4.0 paradigm. AI has the capability to automate the collection and analysis of vast amounts of data from various sensors and systems, providing real-time insights into a company's environmental performance. Machine learning, a critical subset of AI, enables companies to predict trends in key areas such as resource utilization, energy consumption, and emissions. This predictive capability empowers businesses to make more informed decisions aimed at reducing their environmental impact.

Moreover, AI enhances the accuracy and transparency of sustainability reporting by significantly reducing the likelihood of human error, thus ensuring consistency and reliability in the environmental, social, and governance (ESG) data used for assessments [4]. As organizations are under increasing pressure to showcase their sustainability commitments, AI-driven solutions offer scalable, continuous improvements in both green accounting practices and reporting processes, allowing companies to adapt to regulatory demands and stakeholder expectations in real-time.

1.3 Objective of the Paper

This paper seeks to explore the potential of artificial intelligence (AI) in enhancing sustainability reporting and green accounting within the framework of Industry 4.0. It aims to examine how AI technologies can address critical challenges such as inefficient data collection, the absence of real-time insights, and the need for improved accuracy and transparency in sustainability assessments [5]. By automating data gathering and analysis, AI can facilitate more timely and precise reporting on environmental, social, and governance (ESG) factors, thus enabling companies to meet growing demands for corporate sustainability.

The paper presents the case studies and practical applications that illustrate the transformative impact of AI on fostering more sustainable industrial ecosystems. These examples will showcase how AI-driven tools can optimize resource use, monitor environmental impacts, and enhance decision-making processes. Ultimately, the paper will offer actionable recommendations for businesses looking to implement AI technologies to improve their sustainability reporting and green accounting practices, promoting a shift towards more ecologically conscious operations in the age of Industry 4.0.

2. Industry 4.0 and Sustainability

Industry 4.0 represents the fourth wave of industrial transformation, characterized by the integration of advanced technologies that enable more intelligent and autonomous production systems. To fully grasp Industry 4.0, it's important to consider its historical context through previous industrial revolutions. The first, occurring in the late 18th century, was driven by the use of mechanization and steam power. The second, in the late 19th century, introduced mass production and the widespread use of electricity, while the third, in the late 20th century, was defined by automation and the rise of digital technologies. Building on these milestones, Industry 4.0 incorporates artificial intelligence (AI), the Internet of Things (IoT), cyber-physical systems, cloud computing, and blockchain into industrial operations. These innovations enable machines to communicate and collaborate autonomously, making real-time decisions and optimizing production. AI and IoT facilitate instant data collection and predictive analytics, while blockchain technology enhances supply chain transparency and security [6].

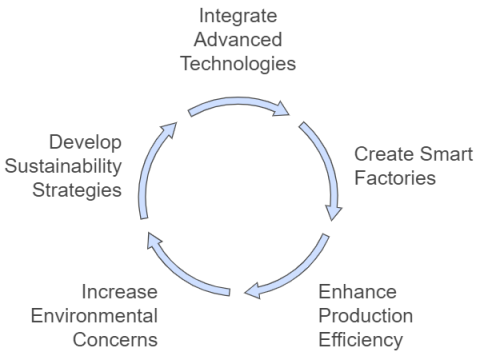

Fig.1 Industry 4.0 cycle

Fig. 1 shows the "Industry 4.0 Cycle," illustrating the continuous process of modernizing industrial practices. It begins with integrating advanced technologies to create smart factories, leading to enhanced production efficiency. This efficiency drives environmental concerns, prompting the development of sustainability strategies. As environmental awareness grows, companies strive to adopt sustainable practices, completing the cycle by further integrating advanced technologies to stay competitive and sustainable.

2.1 Significance of Sustainability

In addition to transforming production, Industry 4.0 has underscored the growing significance of sustainability in industrial practices. Sustainability is now a critical element of corporate responsibility, driven by increasing regulatory pressures, stakeholder expectations, and global environmental challenges like climate change. The rise of environmental, social, and governance (ESG) standards, along with the widespread adoption of the United Nations' Sustainable Development Goals (SDGs), has cemented sustainability as a key business priority. Within Industry 4.0, sustainability is more than just a compliance requirement it has become a source of competitive advantage. Companies with strong sustainability initiatives are better positioned to attract investors, build customer loyalty, and achieve long-term resilience, particularly in the face of climate risks [7]. As a result, businesses are increasingly leveraging Industry 4.0 technologies to reduce their environmental footprint, optimize energy use, and cut down on waste.

2.2 Obstacles in Sustainability Reporting

Despite the heightened focus on sustainability, conventional sustainability reporting systems continue to face numerous challenges. These traditional systems often depend on manual data collection and labor-intensive processes that result in delays and inconsistencies in reporting. The data required for comprehensive sustainability reports, such as energy use, waste management, and emissions data, is frequently dispersed across various departments or external suppliers, making it difficult to gather accurate and up-to-date information. Furthermore, traditional reporting frameworks struggle to incorporate environmental costs into financial reporting, limiting a company's ability to assess the full financial implications of its environmental impact. This disconnect between environmental and financial metrics prevents businesses from making fully informed decisions about their sustainability efforts [8].

2.3 Green Growth and Smart Technology Solutions

Technologies associated with Industry 4.0 offer effective solutions to some of the challenges faced in sustainability reporting. For instance, IoT devices can be deployed across business operations to monitor real-time sustainability metrics such as energy consumption, water usage, and carbon emissions. Big data analytics can then process this information to generate insights into resource efficiency and environmental performance. Cloud computing also plays a crucial role by enabling the storage and analysis of large datasets while promoting cross-departmental collaboration. However, while these tools provide valuable real-time data, they may not always offer predictive insights or automate sustainability reporting. AI can bridge this gap by automating data analysis, offering predictions, and recommending corrective actions, thus helping businesses optimize their sustainability strategies. The integration of AI with IoT and big data enables true green growth, fostering a more sustainable approach to industrial development within the context of Industry 4.0 [9].

3. Artificial Intelligence and its role in sustainability reporting

Artificial intelligence (AI) involves replicating human intelligence within machines, particularly computer systems, enabling them to carry out cognitive functions like learning, reasoning, problem-solving, and decision-making. Within Industry 4.0, AI plays a pivotal role in automating processes, optimizing production, and offering advanced decision-making tools, helping businesses enhance efficiency. AI encompasses technologies such as machine learning, natural language processing, and robotics, all of which are transforming industries. By integrating AI into industrial operations, companies can automate repetitive tasks, manage complex systems, and achieve better sustainability outcomes [10].

3.1 Automation in Data Collection and Processing

A key benefit AI brings to sustainability reporting is the automation of data collection and analysis. In Industry 4.0, AI works alongside IoT devices to gather real-time environmental data like energy usage, carbon emissions, and water consumption—from various sources. This automated data collection removes the need for manual tracking, ensuring a steady flow of

accurate information. AI algorithms process and analyze this data, enabling businesses to produce real-time sustainability reports. This enhances the accuracy of environmental metrics, allowing companies to quickly address sustainability challenges like increasing emissions or excessive energy use [11]. By streamlining reporting processes, AI eliminates human errors, improves efficiency, and equips businesses with the insights necessary to make informed, data-driven sustainability decisions.

3.2 Predictive Analytics for Sustainability Reporting

AI excels in predictive analytics, making it a valuable tool for sustainability reporting. AI models can assess historical and current data to predict future environmental impacts. For example, machine learning algorithms can project energy demands, waste levels, or carbon emissions based on present trends. Predictive analytics enables companies to foresee sustainability risks and capitalize on opportunities, allowing them to take proactive steps to reduce their environmental footprint. With the ability to anticipate challenges, businesses can optimize resource use, cut waste, and improve their environmental performance. AI is instrumental in helping organizations achieve long-term sustainability goals while staying competitive in an increasingly eco-conscious business environment [12].

3.3 Enhancing Transparency and Accuracy

Traditional sustainability reporting is vulnerable to human error, inconsistent data, and subjective interpretation, which can lead to discrepancies in the final reports. AI-driven platforms solve these issues by automating data processing and report generation. These systems ensure consistent data collection and processing, reducing the likelihood of mistakes. Additionally, AI platforms can automatically generate reports that comply with regulatory standards, enhancing transparency and accuracy. This is crucial as the demand for reliable environmental, social, and governance (ESG) data grows, with stakeholders and investors requiring more transparent and verifiable information from companies. Through AI, businesses can meet evolving regulatory requirements, avoid penalties, and showcase their commitment to sustainable practices [13].

3.4 Real-World Applications:

3.4.1 Microsoft: AI for Earth Initiative

Microsoft's "AI for Earth" initiative is a prime example of AI's potential in sustainability reporting. Launched in 2017, this program uses AI to monitor environmental systems, including land use, water resources, and biodiversity, through the analysis of large datasets from satellites, IoT devices, and other sources. The platform provides businesses and researchers with the tools needed to analyze data, implement sustainable practices, and identify areas for improvement. Industries such as agriculture, energy, and manufacturing have leveraged AI for Earth to develop sustainability strategies that optimize resource use and minimize environmental impact [14].

3.4.2 Siemens: AI-Enhanced Sustainability in Smart Factories

Siemens has integrated AI into its smart factories to track sustainability metrics and optimize resource utilization. AI helps Siemens analyze real-time data on energy consumption, emissions, and waste production, enabling predictive insights into future sustainability challenges, such as rising energy costs or increasing emissions. By automating the reporting of ESG metrics, Siemens ensures that its sustainability reports are both transparent and accurate, aligning with global regulatory standards. AI has helped Siemens reduce its environmental impact while maintaining operational efficiency [15].

4. Green Accounting and AI-Driven Optimization

Green accounting is an accounting framework that integrates environmental costs into a company's financial performance metrics. Traditional accounting focuses only on financial transactions, overlooking the environmental impact of operations. Green accounting, however, considers environmental factors such as energy use, waste production, carbon emissions, and conservation initiatives in financial statements. This approach allows companies to assess the comprehensive cost of their activities, including their environmental footprint, leading to more informed decisions. By aligning financial goals with sustainability objectives, green accounting promotes responsible resource management and long-term environmental stewardship [16]. Companies that adopt green accounting can better manage resources, reduce waste, and enhance their corporate social responsibility reputation.

4.1 AI's Role in Optimization

AI plays a critical role in optimizing industrial processes for sustainability by analyzing patterns of resource consumption, such as energy and water usage, and delivering insights to reduce waste or improve efficiency. AI can process vast data from interconnected devices, like IoT sensors, to detect inefficiencies in production systems. For instance, AI algorithms can evaluate energy use at various production stages and recommend adjustments to equipment or schedules to reduce energy consumption during peak periods, thereby lowering a company's carbon footprint [17]. Additionally, AI-powered systems can automate predictive maintenance schedules based on usage

trends, preventing resource-heavy equipment breakdowns and further optimizing resource use.

4.2 AI in Carbon Footprint Monitoring

AI significantly enhances carbon footprint monitoring, a key component of green accounting. Carbon emissions data are often dispersed across intricate supply chains and production networks, making accurate measurement difficult. AI can collect and analyze data from various sources to track emissions throughout the supply chain. Machine learning algorithms process large volumes of data on emissions, fuel consumption, and resource use, providing more accurate carbon footprint measurements. AI enables real-time carbon emissions tracking and offers predictive insights, helping companies identify sustainability risks and take proactive steps to reduce environmental impact [18]. This ability to monitor and forecast emissions in real time is essential for ensuring compliance with carbon regulations and minimizing overall emissions.

4.3 Cost-Effective Green Practices

AI-driven optimization creates opportunities for businesses to adopt cost-effective green practices. By improving operational efficiency, AI minimizes unnecessary energy consumption, waste, and water use, which reduces environmental costs. AI can also optimize logistics within supply chains by identifying more efficient routing strategies, cutting transportation emissions and costs. For companies balancing financial performance with sustainability goals, AI-based systems make green accounting both sustainable and profitable [19]. For example, AI can recommend the most cost-effective ways to reduce emissions, such as upgrading machinery or adopting renewable energy sources, allowing businesses to meet sustainability objectives without compromising profitability.

5. Technological tools enabling AI in sustainability

5.1 Natural Language Processing (NLP)

Natural Language Processing (NLP) is a branch of artificial intelligence that enables machines to understand, interpret, and respond to human language. In the realm of sustainability, NLP is used to automatically analyze sustainability reports, regulatory documents, and corporate communications. This helps businesses stay compliant with constantly evolving environmental regulations. By utilizing NLP, companies can extract vital information from extensive textual data, including policies, guidelines, and sustainability reports, enhancing reporting transparency and reducing the likelihood of non-compliance [20]. NLP tools can identify key sustainability metrics and trends, streamlining reporting processes and improving communication with stakeholders.

5.2 Machine Learning (ML)

Machine Learning (ML) involves training algorithms to recognize patterns and make predictions based on data. In sustainability, ML models analyze large datasets to pinpoint inefficiencies in resource use and sustainability initiatives. For instance, ML can process energy consumption data from sources like smart meters and IoT sensors, detecting patterns and anomalies. Companies can use these insights to enhance energy efficiency by optimizing operational schedules or adjusting equipment usage during peak periods [21]. Additionally, ML can predict future resource needs and potential environmental impacts, allowing companies to address sustainability challenges proactively and make informed, data-driven decisions.

5.3 Blockchain and AI Integration

Blockchain technology provides a secure and decentralized method of tracking and verifying sustainability data, ensuring transparency and accountability. When integrated with AI, blockchain improves the accuracy of sustainability reporting by offering immutable data records. This prevents manipulation or fraud, increasing stakeholders' confidence in the information [22]. Blockchain can trace a product's lifecycle from raw material extraction to disposal, enabling detailed environmental impact reports. The combination of AI and blockchain enhances data integrity and supports real-time sustainability reporting, helping companies respond quickly to regulatory requirements and environmental concerns.

5.4 Software Platforms

IBM Watson: IBM's Watson AI is a powerful platform for analyzing sustainability data. It uses advanced analytics and machine learning to predict trends and identify areas for improvement in environmental management. Watson processes large datasets from multiple sources, helping organizations make better sustainability decisions. It can evaluate the effectiveness of sustainability programs, predict environmental impacts, and recommend ways to optimize resource usage [23].

SAP Leonardo: SAP Leonardo is an innovative platform that integrates AI and blockchain to support real-time sustainability reporting and decision-making. By combining these technologies, SAP Leonardo helps organizations collect and analyze sustainability data while ensuring its accuracy and security with blockchain. This leads to more reliable reporting on environmental, social, and governance (ESG) metrics, helping businesses stay compliant with regulations and build stakeholder trust [24].

6. Challenges and Risks of Implementing AI in Sustainability Reporting:

6.1 Ethical Concerns

As organizations increasingly adopt artificial intelligence (AI) for sustainability reporting, concerns about fairness and objectivity in AI-driven decision-making have emerged. AI systems depend on historical data to train their models, and if this data is incomplete or biased, it can skew the outcomes. For example, if certain environmental impacts are underrepresented in the dataset, the AI system may fail to highlight them in sustainability assessments, leading to incomplete or misleading conclusions [25]. Furthermore, biases may influence the prioritization of metrics, potentially sidelining important social or environmental issues. These ethical concerns call for the establishment of frameworks that ensure the ethical use of AI in sustainability reporting, emphasizing fairness, accountability, and inclusivity.

6.2 Data Privacy and Security

AI-powered sustainability reporting systems require access to vast amounts of data, which often includes sensitive and proprietary information. As a result, ensuring data privacy and security is critical, particularly in light of stringent regulations like the General Data Protection Regulation (GDPR) in Europe, which governs how personal data is collected, processed, and stored [26]. A data breach can result in not only financial penalties but also significant reputational damage. Moreover, companies may be reluctant to share proprietary sustainability-related data, complicating the implementation of AI-driven solutions. To mitigate these risks, organizations must adopt strong cybersecurity measures, enforce regular audits of their data management systems, and establish transparent policies regarding data access and sharing.

6.3 Integration with Existing Systems

Integrating AI with existing sustainability reporting frameworks can be challenging. Many companies rely on legacy systems, which may not be compatible with newer AI technologies, leading to inefficiencies and data inconsistencies [27]. Additionally, the cost of implementing AI solutions can be a significant barrier, particularly for small and medium-sized enterprises (SMEs) that may lack the resources required for full AI integration. Furthermore, a shortage of in-house expertise can hinder the successful deployment of AI technologies. To overcome these obstacles, organizations should invest in employee training, partner with technology providers, and consider a phased approach to AI implementation, allowing for gradual integration and minimizing disruptions.

6.4 Bias in AI Algorithms

AI algorithms used in sustainability reporting are susceptible to bias, which poses a significant risk to the accuracy and integrity of the reports. AI models trained on biased data may produce skewed outcomes. For instance, if historical data focuses primarily on certain sectors or regions, the AI system may overlook sustainability issues in other areas, leading to incomplete assessments [28]. This bias undermines the reliability of AI-driven sustainability reports, potentially misrepresenting a company's true environmental and social performance. To mitigate this risk, organizations must establish rigorous data validation procedures and continuously audit AI systems to identify and rectify any biases that may arise, ensuring comprehensive and accurate sustainability reporting.

7. Future trends in AI and sustainability reporting

7.1 Innovations Driven by AI

The incorporation of artificial intelligence (AI) into sustainability reporting is set to bring about significant advancements that could transform how organizations address their environmental impacts. One noteworthy development is the implementation of AI for ongoing environmental monitoring, which allows companies to continuously assess their ecological footprint instead of depending on sporadic evaluations. For instance, AI algorithms can process information from IoT sensors to monitor aspects like air quality, water consumption, and waste production, offering organizations instant feedback on their environmental performance [29]. Furthermore, automated carbon accounting solutions can utilize AI to measure and disclose greenhouse gas emissions more accurately and efficiently, facilitating better compliance with regulations. In addition, AI-driven sustainability dashboards are expected to emerge, enabling corporate governance teams to easily visualize and analyze sustainability data, thereby promoting informed decision-making and strategic planning.

7.2 Meeting Global Sustainability Objectives

As global sustainability issues become more pressing, AI is likely to take on a crucial role in assisting industries to achieve international targets, such as the United Nations' Sustainable Development Goals (SDGs) and the aim of reaching net-zero carbon emissions by 2050. AI technologies can aid organizations in recognizing and implementing sustainable practices aligned with these objectives by offering insights into resource efficiency, waste minimization, and management of carbon footprints [30]. For example, machine learning models can sift through extensive datasets to identify patterns and trends that inform sustainable supply chain practices, helping companies reduce their environmental impact while improving profitability. Additionally, AI's capability for scenario modeling enables organizations to evaluate the potential results of different sustainability strategies, guiding them in making data-informed decisions to reach their sustainability goals.

7.3 Platforms for Real-Time AI Reporting

The landscape of AI in sustainability reporting is expected to evolve with the introduction of sophisticated real-time reporting platforms. These systems will continuously monitor and refresh sustainability metrics, granting organizations a dynamic perspective on their environmental performance [31]. Through the use of predictive and prescriptive analytics, AI-powered platforms can deliver actionable insights that assist businesses in identifying areas for improvement and addressing risks associated with sustainability initiatives. For instance, AI can evaluate historical data to predict future resource consumption patterns and environmental impacts, enabling companies to make proactive changes to their operations. This transition toward real-time reporting will boost transparency, providing stakeholders with timely access to information regarding a company's sustainability efforts and enhancing accountability.

7.4 Decentralized Reporting on Sustainability

The combination of AI and blockchain technology has the potential to transform sustainability reporting through decentralized, transparent, and secure systems. By utilizing blockchain, organizations can establish tamper-proof records of their sustainability performance, ensuring the security and reliability of the data [32]. This decentralized method can empower consumers and investors to make educated decisions based on up-to-date information regarding environmental performance, thus enhancing corporate accountability and motivating companies to embrace more sustainable practices. Additionally, AI can improve blockchain systems by automating data entry and verification processes, lessening the administrative burden on organizations while ensuring accurate reporting. As decentralized sustainability reporting systems gain momentum, they are likely to cultivate a culture of transparency and trust, aligning corporate practices with stakeholder expectations for sustainability.

8. Conclusion

In summary, artificial intelligence (AI) is significantly changing the landscape of sustainability reporting and green accounting by automating data gathering, enhancing precision, and facilitating real-time tracking of sustainability metrics. By leveraging AI technologies, organizations can efficiently aggregate extensive data from diverse sources, such as Internet of Things (IoT) devices and cloud services, thereby dramatically reducing the manual labor typically involved in reporting tasks. AI algorithms analyze this information to yield actionable insights concerning resource utilization, carbon emissions, and other vital sustainability parameters. Furthermore, the capacity to produce real-time reports allows companies to maintain continuous oversight of their environmental performance, enabling swift responses to new challenges and alignment with regulatory requirements and stakeholder demands. Consequently, AI not only streamlines the sustainability reporting process but also promotes enhanced transparency and accountability in corporate environmental efforts.

References

[1] Tripathi, V., Chattopadhyaya, S., Mukhopadhyay, A. K., Saraswat, S., Sharma, S., Li, C., & Rajkumar, S. (2022). Development of a Data-Driven Decision-Making System Using Lean and Smart Manufacturing Concept in Industry 4.0: A Case Study. Mathematical Problems in Engineering, 2022(1), 3012215.

[2] Awan, A. G. (2013). Relationship between environment and sustainable economic development: A theoretical approach to environmental problems. International Journal of Asian Social Science, 3(3), 741-761.

[3] Elalfy, A., Weber, O., & Geobey, S. (2021). The Sustainable Development Goals (SDGs): a rising tide lifts all boats? Global reporting implications in a post SDGs world. Journal of Applied Accounting Research, 22(3), 557-575.

[4] Sætra, H. S. (2021). A Framework for Evaluating and Disclosing the ESG Related Impacts of AI with the SDGs. Sustainability, 13(15), 8503.

[5] Aldoseri, A., Al-Khalifa, K. N., & Hamouda, A. M. (2023). Re-thinking data strategy and integration for artificial intelligence: concepts, opportunities, and challenges. Applied Sciences, 13(12), 7082.

[6] Paramesha, M., Rane, N. L., & Rane, J. (2024). Big data analytics, artificial intelligence, machine learning, internet of things, and blockchain for enhanced business intelligence. Partners Universal Multidisciplinary Research Journal, 1(2), 110-133.

[7] Danciu, V. (2013). The sustainable company: new challenges and strategies for more sustainability. Theoretical and Applied Economics, 20(9), 7-26.

[8] Savitz, A. (2013). The triple bottom line: how today's best-run companies are achieving economic, social and environmental success-and how you can too. John Wiley & Sons.

[9] Fraga-Lamas, P., Lopes, S. I., & Fernández-Caramés, T. M. (2021). Green IoT and edge AI as key technological enablers for a sustainable digital transition towards a smart circular economy: An industry 5.0 use case. Sensors, 21(17), 5745.

[10] Javaid, M., Haleem, A., Singh, R. P., & Suman, R. (2022). Artificial intelligence applications for industry 4.0: A literature-based study. Journal of Industrial Integration and Management, 7(01), 83-111.

[11] Uddin, M., & Rahman, A. A. (2012). Energy efficiency and low carbon enabler green IT framework for data centers considering green metrics. Renewable and Sustainable Energy Reviews, 16(6), 4078-4094.

[12] Nayak, A., Satpathy, I., & Poddar, S. (2024). The Radical Transformation: Leveraging Green Marketing's Potential for a Sustainable Future.

In Green Transition Impacts on the Economy, Society, and Environment (pp. 166-181). IGI Global.
[13] Rane, N., Choudhary, S., & Rane, J. (2024). Artificial Intelligence Enhanced Environmental, Social, and Governance (Esg) Strategies for Financial Services and Investment Sectors. Social, and Governance (Esg) Strategies for Financial Services and Investment Sectors (May 26, 2024).
[14] Bolón-Canedo, V., Morán-Fernández, L., Cancela, B., & Alonso-Betanzos, A. (2024). A review of green artificial intelligence: Towards a more sustainable future. Neurocomputing, 128096.
[15] Nagib, M. A. (2023). Improving Sustainable Development of the Modern Company: Challenges and Opportunities: master's thesis (Master's thesis, б. и.).
[16] Nicholls, J. A. (2020). Integrating financial, social and environmental accounting. Sustainability Accounting, Management and Policy Journal, 11(4), 745-769.
[17] Shrouf, F., Ordieres-Meré, J., García-Sánchez, A., & Ortega-Mier, M. (2014). Optimizing the production scheduling of a single machine to minimize total energy consumption costs. Journal of Cleaner Production, 67, 197-207.
[18] Hasan, M. R., Islam, M. Z., Sumon, M. F. I., Osiujjaman, M., Debnath, P., & Pant, L. (2024). Integrating Artificial Intelligence and Predictive Analytics in Supply Chain Management to Minimize Carbon Footprint and Enhance Business Growth in the USA. Journal of Business and Management Studies, 6(4), 195-212.
[19] Qu, C., & Kim, E. (2024). Reviewing the Roles of AI-Integrated Technologies in Sustainable Supply Chain Management: Research Propositions and a Framework for Future Directions. Sustainability (2071-1050), 16(14).
[20] Adelakun, B. O., Antwi, B. O., Ntiakoh, A., & Eziefule, A. O. (2024). Leveraging AI for sustainable accounting: Developing models for environmental impact assessment and reporting. Finance & Accounting Research Journal, 6(6), 1017-1048.
[21] Gahm, C., Denz, F., Dirr, M., & Tuma, A. (2016). Energy-efficient scheduling in manufacturing companies: A review and research framework. European Journal of Operational Research, 248(3), 744-757.
[22] Chowdhury, E. K. (2021). Financial accounting in the era of blockchain-a paradigm shift from double entry to triple entry system. Available at SSRN 3827591.
[23] Epstein, M. J., & Roy, M. J. (2001). Sustainability in action: Identifying and measuring the key performance drivers. Long range planning, 34(5), 585-604.
[24] Liu, L., Ma, Z., Zhou, Y., Fan, M., & Han, M. (2024). Trust in ESG Reporting: The Intelligent Veri-Green Solution for Incentivized Verification. Blockchain: Research and Applications, 100189.
[25] Roselli, D., Matthews, J., & Talagala, N. 2019, May). Managing bias in AI. In Companion proceedings of the 2019 world wide web conference (pp. 539-544).
[26] Safari, B. A. (2016). Intangible privacy rights: How europe's gdpr will set a new global standard for personal data protection. Seton Hall L. Rev., 47, 809.
[27] Tsolakis, N., Schumacher, R., Dora, M., & Kumar, M. (2023). Artificial intelligence and blockchain implementation in supply chains: a pathway to sustainability and data monetisation?. Annals of Operations Research, 327(1), 157-210.
[28] Bickley, S. J., Macintyre, A., & Torgler, B. (2024). Artificial intelligence and big data in sustainable entrepreneurship. Journal of Economic Surveys.
[29] Bibri, S. E., Krogstie, J., Kaboli, A., & Alahi, A. (2024). Smarter eco-cities and their leading-edge artificial intelligence of things solutions for environmental sustainability: A comprehensive systematic review. Environmental Science and Ecotechnology, 19, 100330.
[30] Alzoubi, Y. I., & Mishra, A. (2024). Green artificial intelligence initiatives: Potentials and challenges. Journal of Cleaner Production, 143090.
[31] Abdelkafi, N., & Täuscher, K. (2016). business models for sustainability from a system dynamics perspective. Organization & Environment, 29(1), 74-96.
[32] Yadav, S., & Singh, S. P. (2020). Blockchain critical success factors for sustainable supply chain. Resources, Conservation and Recycling, 152, 104505.