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Detecting Greenwashing through Artificial Intelligence: Methods and Challenges

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Abstract

Greenwashing has become one of the critical issues in the age of sustainability-driven business communication, in which companies might overestimate or misreport their environmental performance. The paper is a review of how Artificial Intelligence (AI) can be used to detect greenwashing through a recent development in machine learning, natural language processing, and large language models. It notes some of the major methods including sentiment analysis, topic modeling, knowledge graphs and cross-source data validation in the process of identifying deceptive sustainability claims. The paper also looks at new technologies such as retrieval augmented generation and multimodal AI systems to have comprehensive ESG evaluation. Moreover, the paper presents the key challenges, such as data quality issues, absence of standardized datasets, model interpretability, and the dynamic nature of sustainability language. Literature review shows that AI-based detection is in its nascent stage with limited research. Generally, the paper highlights the importance of transparent, strong, and ethically sound AI frameworks to enhance the level of credibility in sustainability reporting.

Keywords; Greenwashing, Artificial Intelligence (AI), Natural Language Processing (NLP), ESG (Environmental, Social, and Governance), Machine Learning (ML).

INTRODUCTION

Within the past few years, the increase in the urgency of environmental sustainability has led organizations around the globe to embrace more environmentally friendly practices and to report their environmentally-related commitments to stakeholders. Yet, among the real initiatives, greenwashing, or the activity of deceiving consumers and investors, through exaggerating or falsely asserting the beneficial impact on the environment, is common in many companies [1]. This phenomenon erodes confidence, misrepresentation of competition in the market and imposes a global barrier towards sustainable development. With the increasing popularity of environmental, social, and governance (ESG) concerns, there has been a growing demand to have trustworthy and scalable mechanisms that can detect and forestall greenwashing [2]. Conventional methods of identifying greenwashing are based on manual audit, regulatory review, and qualitative content analysis of disclosures, advertisements, and sustainability reports of corporations [3]. Although successful to a degree, the approaches can be lengthy, subjective, and have constraints in processing vast amounts of data in the various forms of social media, financial reporting, and marketing publications. As a result, there is an increasing interest in the application of Artificial Intelligence (AI) to improve the procedure of detection by automation, objectivity, and scalability [4], [5].

AI-based methods, in particular, natural language processing (NLP), machine learning (ML), and deep learning, have demonstrated high potential in terms of studying textual and visual data to find inconsistencies, misleading statements, and patterns that could be an indicator of greenwashing [6]. Such techniques allow the derivation of semantic meaning, sentiment, and contextual cues of large-scale data, which are more precise and effective to detect. What is more, AI can incorporate data collected by various sources, such as corporate reports, news articles,

feedback, and so forth, to deliver a comprehensive evaluation of organizational sustainability claims [7]. Though AI has this potential, there are a number of challenges facing its use in greenwashing detection. These are the absence of uniform definitions and labeled data, the difficulty in interpreting subtle environmental allegations, and the possibility of algorithmic bias. Also, the need to make AI models transparent and explainable is also still of primary concern, especially when it comes to regulation and the ethical dimension [8]. This review paper will summarize and focus on AI-based approaches to detecting greenwashing, indicating some of the most important techniques, trends, application, and challenge of the approaches.

Figure 1: ESG integrity through advanced AI audits

The Role of AI in Detecting Greenwashing

Artificial Intelligence (AI) can be revolutionary in detecting and eliminating greenwashing by allowing automated, scalable, data-driven corporate environmental claims analysis. As the sustainability reporting and the growth of digital content have increased rapidly, AI-based methods, specifically machine learning (ML), natural language processing (NLP), and deep learning offer effective means to analyze large amounts of both structured and unstructured data, sourced in annual reports, sustainability disclosures, websites, advertisements, and social media sites [9].

NLP-based models are also popular in textual analysis and in identifying misleading or exaggerated statements about the environment. Those models are able to detect patterns in the language, tone, vagueness, and discrepancies between the statements of a company and the real performance results [10]. As an example, AI platforms can match the sustainability reports with confirmed environmental indicators or regulatory databases and identify discrepancies. Also, unsupervised and supervised learning algorithms can be used to categorize firms in terms of their risks of engaging in greenwashing, through learning about the past and the instances [11].

Multi-modal analysis also happens through AI, which is used to combine the text, image, and numerical data, improving detection precision. To identify visual marketing on deceptive eco-labeling or imagery, image recognition methods may be used, whilst anomaly detection algorithms may identify unusual behavior in emissions or sustainability indicators [12]. In addition, AI-based applications facilitate real-time surveillance to allow regulators, investors, and consumers to make informed decisions. All in all, AI makes the process more transparent, eliminates human bias, and makes greenwashing detection more efficient. Its usefulness however lies on the quality of quality data, model construction and ongoing validation to affirm reliability and ethical application [13].

AI Detects Greenwashing: Techniques and Technologies

It is the ideal technology for detecting instances of greenwashing since it is capable of working with enormous volumes of unstructured information, including sustainability reports, corporate websites, and press releases [14]. These are a few of the key technologies used in AI.

Natural Language Processing (NLP)

NLP makes it possible to analyze texts and find hidden patterns that might point to problems with greenwashing. Among the crucial duties are:

- **Sentiment Analysis:** the detection of too optimistic, exaggerated language that might indicate an overstatement of environmental credentials.
- **Named Entity Recognition (NER):** the extraction of significant data, such as environmental efforts or emissions measurements, and their relationship to actual information.
- **Topic Modelling:** pointing out that, in contrast to concrete promises with objectives, there is a focus on general and broad principles (such as "sustainability" and "net zero").

A system may analyze both the "what" and the "how" of a company's statements by combining these techniques.

- **Machine learning classification models**

To identify patterns of greenwashing in labeled data sets, supervised learning techniques such as support vector machines, random forests, and deep neural networks can be taught. For example, Text Classification techniques based on the Transformer architecture (e.g., BERT) have been created to correctly detect potentially misleading statements in sustainability reports. These devices have the ability to automate a procedure that has historically needed a sizable crew [15].

- **Big Language Models (LLMs) and Retrieval-Augmented Generation (RAG)**

After being integrated into retrieval systems that offer external benchmark data, LLMs like the GPT versions are able to read and comprehend the narrative reports before moving on to assess the sustainability claims. Techniques based on RAG + LLMs enable a company's ESG disclosure to be compared with documented instances of greenwashing in order to assess reliability and identify any discrepancies [16].

- **Knowledge Graphs and Fact-Centric Evaluation**

These emerging frameworks provide an unbiased evaluation of sustainability using AI by utilizing a knowledge graph with a structure of verified points of data, such as emissions, audit findings, and third-party validation. These algorithms not only identify questionable language, but they also provide justifications for their conclusions.

- **Cross-Source Data Correlation**

In order to find any discrepancies, artificial intelligence may also compare a company's statements with outside data, such as supply chain or satellite emissions data. Models are able to produce a thorough knowledge of the firm's environmental actions by integrating many data sources.

Table 1: Overview of Techniques and Technologies use in AI Detects Greenwashing

S. No.	Technique / Technology	Description	Key Functions in Greenwashing Detection
1	Natural Language Processing (NLP)	AI technique used to analyze and interpret textual data from reports, websites, and communications.	Identifies misleading language, sentiment, vague claims, and extracts key environmental information.
2	Machine Learning Classification Models	Supervised and unsupervised learning algorithms trained on labeled datasets.	Classifies companies or statements as potential greenwashing based on learned patterns and historical data.
3	Large Language Models (LLMs) & Retrieval-Augmented Generation (RAG)	Advanced AI models capable of understanding context and generating insights with external data support.	Evaluates sustainability claims, compares with benchmarks, and detects inconsistencies using external knowledge.
4	Knowledge Graphs & Fact-Centric Evaluation	Structured frameworks linking verified environmental data and relationships.	Validates claims using factual data, improves transparency, and provides explainable AI-based decisions.
5	Cross-Source Data Correlation	Integration of multiple data sources such as reports, satellite data, and supply chains.	Detects inconsistencies by comparing corporate claims with real-world environmental and operational data.

Challenge and Pitfalls in AI-Assisted Detection

AI-powered greenwashing detection has several drawbacks despite its potential:

- **Data Quality and Labelling Bias**

Supervised models necessitate labeled datasets, which call for human knowledge. The resulting output will be biased if the training data contains biases (e.g., different interpretations of greenwashing). Additionally, there are differences in the quality and structure of ESG disclosures, which makes modeling generalization challenging.

- **Evolution of Language and Ambiguity**

Businesses are using more complex terminology to describe their sustainability initiatives. Separating sincere attempts from deliberate ambiguity is sometimes challenging. If static models aren't constantly retrained, this complexity may cause issues.

- **Interpretability in Deep Learning**

Complex neural networks, particularly deep LLMs, have the potential to provide judgments that seem reliable but lack verifiable logic. For instance, in a legal or regulatory procedure, such reasoning becomes essential. Some of the most recent innovations to try to address this problem include "knowledge graphs" and "justification-centric approaches" (like EmeraldMind).

- **False Positives and Negatives**

It can be detrimental to reputations or give false promises regarding risk to blur the boundaries between a genuine

sustainability endeavor and what is known as "greenwashing," or failing to recognize a lack of deceit. Sensitivity and accuracy in risk threshold scores must be balanced.

Key Trends Shaping the Future of Greenwashing Detection

Future applications of artificial intelligence to identify greenwashing will be shaped by significant technology developments.

- **Automated Sustainability Claims Analysis:** In order to find instances when businesses report on their sustainability initiatives while inflating their environmental effect, artificial intelligence algorithms examine every corporate communication.
- **Auditing the ESG Disclosures of Companies:** In order to identify discrepancies, artificial intelligence will employ machine learning to compare a company's publicly published ESG with its real operations.
- **Environmental Risk Scoring:** Companies will receive sustainability risk assessments from artificial intelligence based on both their actual environmental performance and the degree of transparency with which they disclose it.
- **Monitoring Brand Reputation:** AI algorithms will keep an eye on how the public views a business in order to identify any potential problems related to its greenwashing tactics.
- **Monitoring Companies' Compliance With Regulatory Requirements:** AI solutions will assist businesses in adhering to all of the sustainability disclosure regulations that they must follow in any nation where they conduct business.
- Companies will be able to include corporate artificial intelligence into the management of their ESG governance technology as a result of these developments.

Key Applications of AI Greenwashing Detection

Currently, a wide range of industries employ greenwashing detection technologies.

- **Financial:** By giving baseline information about the company's sustainability record, AI techniques help banks and investment management firms to assess supermarket companies' ESG legitimacy before to capital deployment. Because retail enterprises misrepresent their sustainability performance, asset managers are able to remove them from their investment selections.
- **Consumer Products:** To ensure that all product labeling and marketing messaging adhere to all environmental requirements, retailers use AI-based solutions.
- **Energy & Utility Companies:** Energy and utility businesses can evaluate their internal emissions reductions by using AI algorithms to verify the veracity of stated emissions reductions from different providers.
- **Manufacturers:** Manufacturers may utilize ESG monitoring tools to verify sustainability claims about supply chain operations and product manufacturing.
- **Transportation:** Businesses in the transportation and logistics industries utilize AI-based solutions to evaluate their environmental claims and quantify and confirm their emissions.

These illustrations show how sustainable-reporting compliance technology may be used in a wide range of industrial settings.

Table 2: Applications of AI in Greenwashing Detection

Application Area	Specific AI Task/Technique	Data Sources	Goal/Outcome
ESG Report Analysis	Natural Language Processing (NLP), Text Mining, TF-IDF Vectorizer	Sustainability reports, Annual reports	Identifying vague terminology, unsubstantiated claims, or "greenhushing".
Performance-Disclosure Discrepancy	Machine Learning (ML) classification, Regression models	ESG scores, Carbon emission data, Financial reports	Measuring gap between "talk" (marketing) and "walk" (actual performance).
Regulatory Compliance	Semantic analysis, Automated risk assessment tools	Regulatory filings, Environmental regulations	Assisting regulators in identifying high-risk, misleading disclosures.
Social Media Monitoring	Sentiment analysis, Keyword tracking	Social media platforms (e.g., Twitter/X)	Detecting public backlash or discrepancy in consumer-facing communications.
Product-Level Auditing	Computer Vision, NLP for labeling	E-commerce websites, Product packaging	Spotting false "eco-friendly" labels on specific products.

Predictive Risk Assessment	Ensemble models (e.g., XGBoost)	Integrated corporate data sources	Assigning risk scores (low to critical) to company sustainability claims.

LITERATURE REVIEW

(Calamai et al., 2026) [17] focuses on corporate climate communication and offers a thorough and methodologically sound examination of natural language processing (NLP) techniques for detecting greenwashing in textual data. Our study suggests a fractured landscape: "tasks involving ambiguity, subjectivity, or reasoning" continue to be difficult, but other subtasks now demonstrate near-perfect performance under controlled circumstances. Importantly, there isn't presently a dataset of confirmed instances of greenwashing. We contend that ethical NLP approaches that integrate trustworthy data annotations with comprehensible model design are necessary to advance automated greenwashing identification.

(Elsayed, 2026) [18] lay the theoretical groundwork for comprehending AI washing. In this work, we use insights from Information Systems (IS) research on ethics, trust, signaling, and digital innovation, as well as analogies from greenwashing. A taxonomy of AI washing techniques in four key domains—marketing and branding, technical capacity inflating, strategic signaling, and governance-based washing—is presented in this study. We also look at their effects on organizations, industries, and society. Our research and analysis show that while AI washing can result in immediate benefits, it also offers serious long-term risks, such as harm to one's reputation, a decline in trust, and resource misallocation. Additionally, in order to reduce AI washing practices and improve the credibility and dependability of authentic AI systems and technologies, this study looks at current research paths and open topics.

(Jakubczak et al., 2026) [16] uses a purposefully chosen sample of 20 Polish ESG reports benchmarked against ESRS-aligned performance scores from the national "Ranking ESG" to assess the greenwashing detection capabilities of three top multimodal AI systems: ChatGPT 5.1, Claude 4.5 Sonnet, and Gemini 2.5 Flash. To produce comparable evaluations of visual greenwashing, a uniform auditing prompt was used for all instruments. The models did not show negative associations between performance and AI-detected greenwashing, in contrast to all four hypotheses and theoretical predictions; rather, high-performing enterprises often obtained higher greenwashing ratings. These results show that existing multimodal AI systems lack adequate contextual knowledge for ESG assurance and confuse communication complexity with dishonest intent. The article presents strategies for creating domain-specific, ESRS-aligned AI systems for greenwashing detection while highlighting important methodological flaws.

(Mogili et al., 2026) [19] introduce EcoLens GRIE (Greenwashing Risk Intelligence Engine), an AI-based technology that uses machine learning and natural language processing to identify false environmental claims. To find patterns linked to typical greenwashing techniques, such as ambiguous language, hidden trade-offs, and a lack of supporting data, a transformer-based zero-shot classification model is employed. The system calculates a number of analytical indicators, such as environmental confidence, transparency index, deceit likelihood, and credibility score. A thorough sustainability intelligence report for customers is produced by combining these criteria. A React-based interactive dashboard for results display and a FastAPI backend linked with transformer-based NLP models are used in the implementation of the EcoLens platform. The suggested method may successfully detect false sustainability claims and offer real-time risk assessment, according to experimental investigation. The method promotes businesses to implement open environmental communication practices in addition to helping customers make well-informed purchase decisions.

(Dufrane & Thewissen, 2025) [20] examines how artificial intelligence—specifically, language analysis models—can improve the identification of greenwashing in corporate ESG disclosures and how this identification affects investor behavior. Five important linguistic indicators—buzzword density, lack of specificity, emotional tone, hedging language, and candor—are used to create a new Greenwashing Score. An AI co-analyst uses GPT-4 to challenge this composite score, which is calculated using rule-based natural language processing (NLP) techniques in R. This results in a hybrid approach that blends sophisticated language comprehension with interpretability. The study's second section analyzes cumulative abnormal returns (CARs) after ESG report releases to look at the financial effects of greenwashing. The association between greenwashing risk and stock market responses over short- and medium-term event windows is examined using event study regressions (CAR2, CAR5, and CAR60). The findings

indicate that unfavorable investor reactions are somewhat substantially correlated with greater greenwashing ratings, especially when ESG credibility is called into doubt. This study advances the expanding area of sustainable finance and demonstrates the potential of AI technologies in fostering accountability and transparency in ESG communication by connecting AI-driven textual analysis to market results. Additionally, it gives regulators and investors a data-driven way to spot potentially deceptive disclosures and promote more genuine sustainability reporting.

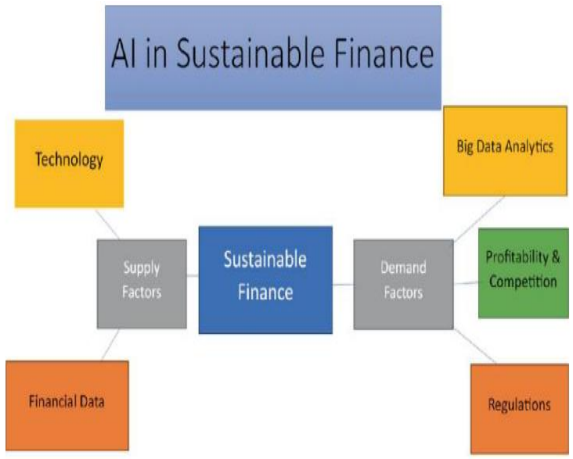

Figure 2: AI in sustainable finance

(Khichi, 2025) [21] investigates how AI-driven technologies might improve the dependability, credibility, and transparency of ESG disclosures in developing nations. The results show that AI-driven assurance systems greatly increase stakeholder confidence, boost regulatory oversight, and minimize information asymmetry. However, they also highlight issues with data quality, algorithmic bias, regulatory preparedness, and ethical governance. By describing future research and policy approaches and putting forward a conceptual framework for AI-enabled ESG assurance specific to developing economies, the paper adds to the body of ESG literature. In order to guarantee the appropriate and efficient use of AI in sustainability assurance, it emphasizes the necessity of cooperative governance comprising regulators, businesses, auditors, and technology suppliers.

(Ren et al., 2025) [22] examines how the rate of AI penetration affects the level of corporate greenwashing and attempts to evaluate AI's potential for improving environmental performance and lowering false disclosures. The findings of this study demonstrate that the use of AI can prevent businesses from engaging in greenwashing, and that this inhibitory impact is further strengthened by green innovation initiatives. AI has a stronger deterrent effect on corporate greenwashing in state-owned businesses and those with Party affiliations. This decrease in greenwashing is more likely to be seen in businesses that are strongly impacted by Confucian culture, have greater public attention for their environmental effect, have less rivalry in the market, experience more severe pollution, and have less financial limitations.

(Sharma, 2025) [23] examines how greenwashing issues and the promotion of genuine, open communication are being addressed by artificial intelligence (AI), which is transforming ethical branding. It draws attention to the changing tastes of Gen Z and Millennials, whose desire for sustainability pushes companies to use cutting-edge tactics. We look at how AI may be used to monitor supply chains, automate sustainability reporting, and customize ethical narratives using data-driven insights. Case studies that show how AI helps companies win over customers by guaranteeing accountability and verifiability include Patagonia's open practices and Everlane's extreme openness. The study also explores the moral conundrums raised by AI in branding and marketing, highlighting the need of data protection and openness. Brands can satisfy the changing demands of the environmentally conscious youth while promoting a culture of accountability and trust by using AI to create genuine, eco-friendly storylines.

(LOIOLA & SOUZA, 2024) [24] shown a steady rise in studies on greenwashing techniques. Artificial intelligence (AI) developments have also shown themselves to be a valuable tool for efficiently and precisely processing vast amounts of textual information, such those found in sustainability reports. The literature on the application of AI and machine learning (ML) to identify greenwashing in ESG (environmental, social, and corporate governance) reports is thoroughly reviewed in this paper. The results show that, despite technological advancements, the use of AI and ML to detect greenwashing is still a developing field with plenty of room for further study, underscoring the need for more reliable and comprehensive techniques to guarantee the accuracy of sustainability disclosures.

(Nainwal & Dua, 2024) [25] examines how AI may enhance environmental results in a variety of businesses. However, some businesses create false narratives by making inflated marketing claims about the environmental advantages of their AI technologies. The emergence of "AI hype" in corporate environmental reporting is revealed by

this study. The term "AI hype" describes the exaggeration or falsification of AI's environmental benefits, which results in "greenwashing." This happens when businesses overstate the environmental advantages of implementing AI and machine learning. According to our research, businesses that engage in AI hype are more likely to discuss environmental issues in their reports while also causing pollution levels at their facilities to rise. This tendency is seen in many other industries, indicating how pervasive the problem of AI hype is. Such acts might undermine public confidence and harm people's reputations, which could result in legal issues and impede future attempts at innovation. Regulators, executives, and investors must be aware of the possible risks associated with AI hype as more funds are allocated to AI research and development.

(Seele & Schultz, 2022) [26] suggests a conceptual mapping to highlight key characteristics and connections that enable a knowledge transfer from the more recent machinewashing phenomena to the well-known greenwashing phenomenon. We take into consideration pertinent differences, highlighting potential conceptual limits. The paper tackles the structural analogy and machinewashing peculiarities using a "reasoning by analogy" technique, which results in a new and theoretically grounded model of machinewashing. As a result, machinewashing is described as a tactic used by businesses to engage in deceptive conduct (communication and/or action) about moral AI and algorithmic systems. Machinewashing is the practice of communicating false information regarding ethical AI using words, images, or the AI's underlying algorithm. Beyond greenwashing, machinewashing may also be utilized for symbolic activities like (covert) campaigning and preventing more stringent regulations. The paper suggests a machinewashing model and a collection of theory-related research questions on the macro, meso, and micro-level for future machinewashing research by describing the theoretical underpinnings of the established greenwashing domain and their relationship to particular research issues. Finally, we highlight our shortcomings and discuss the practical consequences for organizations and governments.

CONCLUSION

Greenwashing identification has enhanced the need to have transparency, accountability, and trust in the core sustainability practices of the corporations. This review shows that Artificial Intelligence can be used to solve this problem through the provision of potent instruments to analyze this problem on a large scale and in an automated and data-driven manner. Natural language processing, machine learning classification, knowledge graphs, and large language models have played an essential role in making it much easier to find inconsistencies, misleading stories, and unsubstantiated sustainability claims. Besides, the multi-source and multi-mode data integration has enhanced the intensity and precision of the greenwashing detection in industries. Nevertheless, even with such improvements, there are still a number of limitations. Difficulties associated with the data availability, labeling bias, changing business language, and uninterpretability of complex AI models remain an obstacle to trustworthy implementation. Besides, false positives and negatives bring up concerns in the context of regulatory and financial decision-making. The literature also suggests that the existing AI systems tend to be indifferent to context and need to be domain-tailored. The research in the future is expected to be aimed at the creation of standardized datasets, the enhancement of explainable AI, and the establishment of collaboration between regulators, researchers, and industry players. These struggles can be conquered through AI, which will become instrumental in facilitating genuine sustainability efforts and enhancing ESG governance in the world.

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